AN ACTION RESEARCH INVESTIGATION INTO THE EFFECTIVENESS OF NUMBER TESTING OF A GROUP OF YOUNG ADULTS WITH LEARNING DIFFICULTIES IN A FURTHER EDUCATION SETTING

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Abstract

This was an investigation into the testing of number skills of young adults with learning difficulties in the further education sector. Four male students were tested for a range of numeracy skills using recognized methods. The participants' ability to count non-concrete sets was also explored using drumbeats and counting using only touch was explored using a feely-box. The participants' ability and the adequacies of the tests were assessed with regard to the participants' results. There was the conclusion of the need for further education educators to recognize the elemental steps involved in developing the ability to count, the need for more targeted tests for subitising, numerosity and ordinality.

Dedication

This work is dedicated to
Loci

Acknowledgements

First and foremost I need to thank Alison for all the support she has given to me throughout this project; she tolerated much in her normal giving, quite way and for having so much faith. I owe a great dept for the proofing carried out by Celia, Olivia and Jenny; it was a herculean job due to my dyslexia and rudimentary grammar skills. A would like to thank Penny and Pat for the debates, the ideas and guiding me along this journey. I would also like to thank all those participants both primary and secondary for joining in and helping with such enthusiasm. I need to thank Loci for his continuous company and the walks we shared that gave much needed thinking time and space.

Contents

Introduction

The original working title of this research was an investigation into 'whether innovative teaching interventions can improve the development of number skills in adults with learning difficulties. Furthermore, if no amount of intervention will have an effect, can practical non-number-based strategies be developed for use in everyday life to overcome any number deficiencies?'

The issue: the need for number skills

Number skills and the successful mastery of these skills play an important and fundamental role in living an independent life in modern society (Nye et al., 2001; Buckley, 2007; Butterworth, 2000). If these number skills can be enhanced for the participants in this study then it will have been worthwhile.

The importance of number skills would appear to be underappreciated in the field of educational research concerning children with learning difficulties, if one were to compare the amount of studies carried out on number skills with the amount of studies on communication skills development. What research there is does show that number skills tend to be less developed than language skills (Buckley, 1985; Carr, 1988; Sloper et al, 1990). This imbalance in numeracy development and the development of language was evident in the day-to-day encounters with the learners in the department within which I worked. Many learners could express themselves well in their

spoken language, and sometimes in a written form, yet could not perform the most rudimentary number task. This was one of the reasons for pursuing this line of enquiry.

There is a move to address the imbalance at the national level; all schools, including special schools, have to deliver the National Numeracy Strategy, which should ensure that children with learning difficulties develop better number skills than in the past. The participants in this study would have only partially benefitted from this change, as they are of an age to have had only two years of the National Numeracy Strategy, which was introduced in 1999.

However, there was already some evidence of a small change in the imbalance in number skills of some children with Down's syndrome. This improvement was noted before the legislative demand for greater equity in numeracy training (Nye et al, 2001).

The problems encountered whilst teaching adults with learning difficulties basic number skills was the inspiration behind this research study. The research was carried out within a further education college setting where I was a teacher, using a group of young men who attended the college three days a week on a life skills course. For the carers of these students, the concerns were understandable due to the lack of skill demonstrated by the learners and the impact this has had on their everyday lives. These concerns often led to requests for help in giving their charges better number skills, especially in everyday situations that required the telling of time and the handling of money.

The lack of realism

There was often a lack of realism in these requests, as many of the students demonstrated no ability to comprehend cardinality or successfully add small numbers. Yet parents and guardians expected their child or charge to be taught the skill to work out that ten lots of ten pence pieces were the equivalent of a one pound coin, or that half an hour after quarter to three was quarter past. Even without the problems of different forms of representation of amounts, numbers or coins, and the use of sixty minutes in an hour as a base, the number skills require a great leap in skill and ability. Considering whether these learners could develop number skills or whether the time and energy spent attempting to improve these skills could be used more effectively led to this investigation. It was felt that the time could be better utilised to develop non-number strategies, specific to an individual's needs, to help them in their everyday life and this would overcome a lot of the frustration felt by the teachers and the students alike. An example of practical application would be that if you only ever catch the number 55 bus to college, that is the number you need to know, not as a cardinal number but as an identifier. There is no need to know that it comes on the number line after 54 and before 56, or that it can be divided by 5 eleven times. All you need to know is that when the bus with 55 stops at your stop, not the one on the other side of the road, you get on it.

I felt that if parents and guardians came to realise that no or little improvement in number skills would take place, then meaningful dialogue on how best to develop strategies for their child or charge could begin to take place. This

would, however, require good-quality evidence and not just an opinion if it was to have any credence.

Why me?

I was ideally placed to investigate this issue, as I had the time available and a genuine interest both in improving the life experience of the students I worked with and in number skills. I was taking a year's sabbatical leave and was developing the skills of an educational researcher. This gave me time to carry out the research and an ability to design a research method to investigate the issue.

The United States disabilities movement considers itself the last civil rights movement (Barnartt, 2010), and although many other oppressed groups may question whether their fight for justice is over, anti-discriminatory legislation in the United Kingdom with regard to disability has lagged behind other legislative Acts (OPSI, 2005). This indicates that it has taken time, for the legislation at least, to recognise the discrimination felt by people with a disability. Therefore, any amount of emancipation within the lives of the students I work with will be of benefit, no matter how small. If this benefit is in improved number skills it will be greatly welcomed, but if it is in developing other ways of improving the quality of everyday living this will be of equal worth.

The literature

Initially, it was felt that the best way to investigate number skills was through looking at the participant's ability to count. The composite parts of counting

skills were recognised by Gelman and Gallistel in 1978; this seemed a good place to start a literature search as their model of counting is generally regarded as accurate.

After reading McConkey and McEvoy (1986) their testing regime for assessing counting skills was adopted.

Another author of interest was Butterworth; he theorised on how the brain comprehends small amounts and used brain imaging techniques to investigate the workings of the mathematical brain. Butterworth was interested in numerosity and subitising, which, after gathering the data, were recognised as being of greater importance than had originally been realised; subsequently the need to explore the literature on these two connected skills was recognised and fulfilled. This exploration of the literature revealed the work of Sue Paterson on the subitizing skills of infants and adults with Down's and William's syndromes and methods for testing this preverbal skill. Numerosity and subitising are the abilities to recognise the number of objects in a set rapidly.

Also, post data collection, Julie Sarama and Douglas H. Clements published *Early Childhood Mathematics; Education Research* (2009), which has been a valuable source regarding the other numeracy topics that it was subsequently necessary to explore in response to the data gathering.

Research methodology

It had been intended to be as objective as possible in the research and there was a strong desire to use a scientific-based experimental-type framework.

My first degree had a science base and I unquestioningly accepted the scientific method as the best way to test a hypothesis. Therefore, the design reflected a scientific test of the hypothesis endeavouring to control or at least account for all the variables that could undermine the results. It would have been wise to follow the advice that the methods should be shaped by the questions and not the other way round (Plummer, 2001).

Perhaps the wrong questions were asked, as the experimental methodology did not work and the action research methodology was adopted. Any reservations that were held about using this design were soon overcome, as in researching this methodology awareness grew of the particular strengths it had. The ability for this method to respond quickly to the changing circumstances was a real strong point, along with its potential to have a real effect at a local level. Action research can be an emancipatory tool, and its impact can be seen at the local level. This made it a very attractive research method and as every new piece of data seemed to change the question and direction of the research the flexibility became invaluable.

Research methods/tools

The intension was to use McConkey and McEvoy's (1986b) four tests of counting ability as a baseline. After the participants' datum levels were recorded the teaching interventions would take place over several weeks and then the test would be reapplied. This would allow the monitoring of their effectiveness and the progress being made by the participants. The group would be used as its own control, being tested prior to the baseline test at the same days' interval as the intervention was to take place.

This appeared to be an objective process, but as the research unfolded the level of objectivity attained and the restrictions of recording in a detached manner became apparent, along with the need for the procedure to be changed. As the data were recorded it was difficult to contextualise what was being observed. It was necessary to move towards a more subjective approach. This approach included notes on other factors and thoughts, as this ultimately suited the method better.

Ethical considerations

The primary consideration was the vulnerability of the participants and whether they could give meaningful consent. The position of authority and trust that had been developed by the researcher with the learners, staff, parents and carers made for greater responsibility. There was also the ethical issue of how to distribute and publish the knowledge gained to the best advantage of the participants. The question of who owned this knowledge, the researcher or the participants, had to be considered. It was believed that the learners should have access to the data, but in a meaningful form to them. Also, consideration had to be given to the impact on colleagues and the risk of professionally damaging them. The gathering and publishing of the data could compromise other teachers or cast their methods of teaching or behaviour management in a bad light. Even research with the best emancipatory intentions is riddled with ethical considerations.

The value of this research

It was hoped that this research would add to the body of general educational knowledge or contribute to better practice in my own special educational department. There was optimism that the lives of the participants and their families could be improved through a greater understanding of how they used, or did not use, their number skills.

Chapter 1

LITERATURE REVIEW

This chapter is a review of some of the extensive literature on numeracy that relates to this research into basic numeracy skills and adults with learning difficulties. Consideration is also given to the mental processes involved in using these skills and how children learn and develop the concepts of numbers. The initial intention and interest was around exploring parallels in language development and the development of number skills, particularly the concept of a sensitive age. As the research progressed and it became apparent that this was too large a venture, the focus changed to one of a small-scale action research and intervention project. This research and intervention were planned to take place in a further education setting with young adults with learning difficulties. The intention was to explore whether innovative number teaching and interventions would improve the participants' mathematical skills or whether no amount of intervention would improve their ability to use numbers.

Initially a baseline test was planned to ascertain each learner's starting level; this analysis took the form of testing counting skills. Much of this literature review surrounds the research and theorising available on the skills associated with counting. As the initial tests took place it became apparent

how complex and relatively advanced a skill counting is: beyond the ability of some of the participants. Before any research was even attempted into effective forms of innovative interventions the search to establish the level at which the participants were functioning had to be undertaken. Part of the action research cycle is reflecting; this reflection process made it necessary to explore other basic mathematical skills. Hence, after reviewing the research on counting, there is consideration of the available literature on subitising, numerocity, ordinal numbers and ordinality skills. These skills could be used to illuminate more fully the participants' number skills. There is also a review of a test on the preverbal skill of subitising and some of the implications of this investigation.

Four theoretical frameworks of number development

How rudimentary number skills are gained is the fundamental question of this research. The developmental stages that children go through should inform the teaching strategies and when and how they are carried out to optimise their effectiveness. There have been three theoretical frameworks that describe the development of the understanding of numbers and explain a child's development of number skills (Sarama & Clements, 2009).

Nativism: the ability to handle number is innate or due to early developmental capacity within the child.

Empiricism: the child develops numerical understanding through interaction with reality and their knowledge.

Interactionalism (constructivism): the child develops or constructs knowledge structures by building on previous less sophisticated structures. What separates this from empiricism is that the interactionalists believe that the initial structures are prerepresentational. Children develop their understanding of the world rather than discovering it or having it revealed.

Hierarchical interactionalism: having examined the theoretical frameworks Sarama and Clements (2009) suggest another framework, hierarchical interactionalism, which is a synthesis of interactionalism and empiricism. They recognise a level of innate ability and also the importance of experience and the need to build structures.

The potential impact on this study

The nativist stance implies that children without fully developed fundamental abilities will never develop number skills, regardless of their life experience. This would have implications for the research as no matter what interventions were used there would be no change in the number skills of the participants. This would also impact on the feedback given to the participants and their carers and imply careful consideration on advising them how to use this information effectively.

The empiricist stance gives more hope to the child with learning difficulties as skills can be learnt and developed. The hope would be that the research could identify those interventions that would improve the participants' number skills and hence their quality of life.

The interactionalists and hierarchical interactionalists hold that the capacity of a child to develop number ability will be influenced by their innate aptitude and the quality of their life experience, including the teaching they receive. The problem is finding out how much is nurture and how much is nature? Assuming that the interactionalists are right, the challenge for this study is to see if better life experience can be found to overcome any innate deficiencies that the participants may have.

Sarama and Clements (2009) are very positive and optimistic in their belief that number skills can be improved for all typically developing children. The hope is that this optimism can be held equally for atypically developed adults such as those participating in this study.

These four theoretical frameworks give a broad overview of how humans learn number skills; what follows is a review of the literature on what specific basic number skills are and how they are developed.

The components of counting

Counting appeared to be a good place to start the investigation into the participants' number skills as this is often the first number skill a child is taught (Lave, 1988; Rogoff, 1990).

Object counting

There are four elements to an object counting system: recognising that a set of objects needs to be counted, a desire to find out how many there are, the

counting itself and the outcome of a set of counted objects (Steffe & Cobb, 1988).

The counting itself and the importance of counting words

For this research project an ability to say the counting words may not demonstrate any counting skill and the participants' skills will require further investigation.

The recitation of counting words per se remains important to developing number skills and should not be undervalued; research supports the theory that very young children develop many essential language associations through these activities (Fuson et al, 1982). Research also suggests that children as young as three demonstrate certain rational counting principles, underlining the importance of reciting counting words at a very young age (Aubrey, 1997; Gelman & Meck, 1986 Schaeffer, Eggleston & Scott, 1974).

The need to practise and master the counting words and the fact that it is viewed as being of such underlying importance may lead this to be an important intervention with the participants in this study. Counting games and the recitation of counting words could prove an effective way of improving the participants' counting skills.

Counting games

Counting games are an important component of early education; nursery teachers are encouraged to incorporate counting games within their numeracy sessions including those sessions with Down's syndrome infants (Bird &

Buckley, 2001). However, these are often not real counting games but a stage needed to develop counting skills; they are really games to learn the counting words and to place them in the correct order, known as the stable order principle.

Being able to say the counting words does not, in itself, indicate number skills and there is a distinction between a child at the stage of being able to recite the number words in sequence but not realising that they have a corresponding cardinal value and the child at the stage of realising that there is a corresponding value (Vergnaud, 1994). In the first stage there is nothing to distinguish this sequence from any other word sequence, such as the alphabet or do, re, me, fa, so, la, te, do. Why these orders are important is still not apparent to the child other than the praise received for getting them right (Sarama & Clements, 2009). In the second stage of development there is a level of understanding of some of the qualities of a number; these qualities that a child attaches to a number require the child to grasp the concepts of one-to-one correspondence, equivalence and order relationship (Gelman & Gallistel, 1978).

The need for counting words beyond three

One recent study has questioned the need for counting words at all; this research (Butterworth et al, 2008) and the findings from studies on the counting skills of certain Amazonian tribespeople (Gordon, 2004; Pica et al, 2004) make the claim that with only a few number words children can still demonstrate numerical thought. This research may eventually lead to a different appreciation of numbers and the way they can be taught; however, it

should be noted that these tribespeople demonstrated low-level number skills. This would imply that a greater mastery of counting and numbers is needed to function above low-level number skills. It was deemed necessary in this research to make a meaningful mathematical impact on the participants' lives.

The impact of your mother tongue

The importance of the stable order principle means that in the British education system a learner is required to know the English names of the numbers 'one, two, three …' and the Arabic representation 1, 2, 3 … and to be able to place the numbers in the correct sequence. Developing these skills is a prerequisite for later mastering the concepts of the decomposition of numbers, combining numbers to create greater numbers and base work (Geary, 1994). If a participant does not have this skill then any higher-order skills will be limited.

Learning the number words can be problematic and not all languages make learning the number words as easy as it could be. For example, in Germanic or Romance-based languages there is a particular problem with learning eleven and twelve. There is a need to learn the special nature of these numbers in relation to the number ten. John Conway, Mathematics Professor at Princeton, posted the following interesting explanation on this peculiar relationship on 'The Math Forum':

> There seems to be a natural tendency in language for the first few terms of a sequence to be treated specially. Thus in English, "eleven" is really "one left (over)", and "twelve" is "two left", so that

> the implied "after ten" is omitted. But from thirteen on it seems that we should explicitly mention the "ten", since we're getting so far away from it that we might otherwise forget it! (Conway, 1995)

Conway's explanation as an intervention

It is possible that if any of the participants were to struggle with these words then Conway's explanation, if given to the participants, would ease the learning of the apparently randomly named numbers eleven and twelve and consequently the post-number-ten numbers. This is dependent on the language and comprehension skills of the participants and the quality of the explanation.

Old Chinese

There are other problems with learning the English number words that are highlighted when compared with other languages. For example, in Chinese and Asian languages based on Old Chinese, the number system has a more logical and simpler structure; the way the number sequence develops facilitates the learning of the number words post-ten. In Chinese the number names of one to ten are as random as they are in English. At ten there is a significant change in the structure as there is no 'one left over ten' but instead the more logical ten-one, followed by ten-two, followed by ten-three; in effect, once the first ten numbers have been mastered, the next nine are easy or at least easier than in English. What happens at twenty though? Here again there is a significant difference from English number words; the decades are named as multiples of ten, so twenty is two-tens and thirty is three-tens. There

are obvious advantages to this system as once one to ten have been mastered the step to extending the number sequence requires only the learning of a few new rules of counting grammar. These changes have a significant impact on the speed of development of the skill of counting in children speaking Old-Chinese-based languages (Han & Ginsburg, 2001) and subsequently on developing early mathematical ability. The complexity of the English system means that the teens take longer to learn (Baroody, 1992) than in any of the Old-Chinese-based languages.

A less obvious advantage of the Old-Chinese-based systems is that the one-to-ten sequence becomes stable more quickly as reciting in the teens and decades also gives practice of the one to ten numbers (Aunio et. al, 2004).

If the complexity of the number words has an influence on those children following a typical developmental pattern it follows that the complexity of number language for those children with learning difficulties must be greater.

The implications for this research were that any deficiency in the use of counting words may be overcome by greater practice; as in the Old Chinese case, the more practice the greater the mastery.

The possible issue for the participant may be the ability to articulate the number words and therefore other forms of representation of numbers may demonstrate a greater number skill than verbal counting does.

Alternatives to number words

There is a question over the necessity for number words in developing and mastering numeracy skills (Gelman & Butterworth, 2005). The Pirahá and Mundrurukú tribes of the Amazon do not have number words above five, and they use these with little constancy, yet they can carry out non-verbal number tasks up to the number eighty. This could imply that by developing number strategies other than counting one can live a more fulfilled life both in our society as well as in the Amazon. Developing strategies relevant to the individual may prove an important way forward for the participants in this research.

Stages of development of the stable order principle

The Amazonian tribespeople apart, it would appear that language is still a major component of developing a clear concept of numbers (Weise, 2003).

So far we have only considered the stable order principle in terms of comparing the number words and the possible impact of the apparent lack of logic in their naming in the English language. A more detailed study shows that true mastery of the stable ordering of the number words is attained through several stages (Fuson & Hall, 1982).

The first phase of learning the counting words is as a singular sequence where the individual number words can not be taken independently out of the sequence (Fuson & Hall, 1982). This would indicate that no concept of quantity is available to the child. Most learners demonstrate several stages of

stability whilst learning this first phase of the counting numbers (Fuson et al, 1982).

The first stage of this first phase is when the words in the sequence do not have individual meanings and can only be produced when they are part of the whole.

This sequence can be made up of three distinct parts. The sequence starts with a stable conventional section where the number words are recited correctly in the right order. The next part is made up of a non-conventional stable sequence; here the number words are recited in an unconventional order but in a fairly stable order. Porter (1999) noted that other researchers had not seen this stable but non-conventional counting (Wagner & Walters, 1982; Baroody & Price, 1983), proposing that this may in fact be a product of the repeated testing of the participants.

There were potential validity implications from Porter's observation that repeating the tests may affect the results.

The next part of the sequence is a non-stable non-conventional section where no consistencies in either number names or orders are demonstrated. Greater mastery of the counting sequence is demonstrated when the stable conventional section is extended.

I have often observed these counting sequences recited in the classroom and through a lack of understanding they are often used as evidence by both staff and carers that students possess good number skills. A greater awareness by

teachers, classroom assistants and carers of the developmental stages would assist assessment and progression.

Stages of mastering the counting words

After the words have been learnt with a level of stability the subsequent stage has five distinct levels of mastery (Fuson et al, 1982):

String level – the words are not separate nor are they thought of as individual objects.

Unbreakable list – the words are separated, they can be taken out of the list and consequently they are thought of as separate objects; total mastery of the first phase is not necessarily needed to start the second phase. There is a weight of research to support the premise that children can learn the counting words before any understanding (Briars & Siegler, 1984; Frye et al, 1989; Wynn, 1990; Caycho et al, 1991; Fluck & Henderson, 1996).

Breakable chain – the list can be produced from a different starting number other than just one; this is a necessary skill in ‘counting on’, which is used later as an adding strategy.

Numerical chain – the words become distinct units that can be counted.

Bi-directional chain – the chain can be counted in either direction; this ability to sub-divide the chain permits the concept of part–whole, which is important later for the development skills used in addition, subtraction, multiplication as well as division.

Any deficiencies in these stages of development could have an impact on the level of counting ability that the participants were liable to demonstrate. The various developmental phases gave a greater level of detail of any deficiency and this level of detail made more targeted interventions possible.

The five elements of counting

Knowing the counting words and being able to recite them in the correct order are an important element but only part of the skill of counting. Knowing the words in order is the stable order principle and the order of the words must remain the same and stable (Gelman & Meck, 1986). There are four additional elements of the stable order principle that are required to count successfully; the five subskills or components are:

One-to-one correspondence: only counting each object once.

The stable order principle: the order of the counting words must not vary; they always remain in the same order.

The cardinal principle: the last number counted corresponds to the number of objects there are in the set.

Item identification: (Geary (1994) calls this **abstraction**) any items may be grouped together and counted.

The order indifference principle: it does not matter which object in a set you count first or in what order you count them (one-to-one correspondence must be maintained) (Gelman & Meck, 1986).

One-to-one correspondence

After gaining a high level of competence in the stable order principle, one-to-one correspondence needs to be mastered. The child needs to achieve success at the numerical chain level to perform one-to-one correspondence correctly. It is necessary for the counter to realise that each word is a distinct unit and that these words can be assigned to individual objects.

In the development of one-to-one correspondence there are again recognisable stages (Alibali & Di Russo, 1999); the early stage requires two types of skill: those of the counting words in order and keeping track of the objects being counted. In the early stages gesturing was a necessary aid in helping with these two components of one-to-one correspondence and touching the objects was a particularly effective method of aiding the counting of objects (Alibali & Di Russo, 1999).

Potential developmental errors in mastering one-to-one correspondence

Many types of error were identified by Fuson et al (1982) during the development of one-to-one correspondence, which included early developmental errors where objects were pointed at but no counting word said. Another error was found to be when an object was pointed at and more than one counting word attributed to the object. This would indicate that the child was probably still at the string stage of development and had not developed the concept of the words as distinct units and could not then attribute them to individual objects.

Errors in later stages of development were associated with delays in saying the words. These delays were produced when the method of moving the object was used instead of pointing at the object. It was surmised that the delays in moving the object led the child to forget the words and hence broke the sequence. When moving objects in the counting process there is a need for greater concentration and a superior ability to focus on the task than there is when counting through pointing. An error is sometimes produced when using the moving method as there is a tendency for the child to play with the objects, using them to construct something else. The objects become a distraction. Another common error is when more than one object is moved for each counting word.

These are all potential problems when administering the counting tests; they require attention from the test administrator.

When these errors are no longer present and one-to-one correspondence can be added to the child's stable order skills, cardinality can start to be addressed. At first, for many young children, counting to establish 'how many' is not the purpose of the counting activity (Fluck & Henderson, 1996). The child does not understand that counting is not an act in itself but may indeed have another function; there may be some other reason for undertaking the task than saying the words and attributing them to objects. These children are confused by questions that may indicate any other purpose to their counting activities than recitation (Munn, 1994).

Even when a level of understanding is gained and the child gives the last number counted as the cardinal value of the group of objects this still may not

demonstrate cardinality (Fuson & Hall, 1982). This could be the next step in meeting the request of the adult asking ‘how many’ and giving the last number. This lack of complete understanding was exposed when children were asked what the last number referred to; the children indicated only the last object, not the complete set.

The leap in understanding required in moving from recitation by rote to cardinality is great. It is argued that this leap requires a greater use of the visuospatial ability than just language ability (Sarama & Clements, 2009). This could be due to the need to point to objects to aid one-to-one correspondence.

Item identification (abstraction) and order indifference

The other two components of counting item identification (abstraction) and the order indifference principle are advanced skills and were seen as relevant to this study.

Studies with atypical developers

Children with Down’s syndrome can only count by rote and do not understand any more advanced mathematical thinking (Cornwell, 1974). Gelman and Cohen (1988) found that when attempting to solve novel counting problems children with Down’s syndrome were not as able as mental age matched pre-school children. They concluded that the results supported that typically developing children make use of counting principles and those with Down’s syndrome cannot. However, two of the children with Down’s syndrome were 'excellent counters' who were able to make use of principles of counting; why

these two were ignored has been questioned (Porter, 1999). These two children would suggest that children with Down's syndrome can use counting principles and that all Down's children may benefit from appropriate interventions (Nye et al, 1995).

It has been found that there was no difference between two groups of children in performance tests of the counting principles when the Down's group was matched with typically developing children of a similar developmental level (Caycho et al, 1991). The conclusion was that children with Down's syndrome can make use of counting principles and their counting ability is related to their available vocabulary and not to the syndrome.

The ability to use the counting principles may be a function of the educational programme the children were engaged in, and it may not be possible to assume that all learners with Down's syndrome will develop these skills (Caycho et al, 1991). This does imply that with the right educational programme more Down's syndrome children could learn better counting skills.

Counting: domain-specific or a general-domain process?

Fodor (1983) suggested that there are two types of cognitive ability: specific cognitive modules and general-purpose central processes. Specific cognitive modules are specialised cognitive functions that process only one fact received by the brain from the senses. For example, there is one module that is responsible for the recognition of the shape of an object, while another recognises colour. Due to the specificity of their role these cognitive modules work extremely quickly and are always engaged whether we wish them to be

or not; they are not reliant on conscious thought. Hence, when you see a triangular road sign, you cannot but see that it has three sides that make it a triangle or that it has a border that is red. General-purpose central processes take longer to work and we make a choice whether to engage them or not. We have to learn to use these central processes; examples of these types of activities would include writing with a pen, using a computer keyboard or carrying out long division.

Karmillof-Smith (1992) explains, in *Beyond Modularity*, that Fodor proposed that domain-specific cognition exists in humans and that Piaget supported an opposing view of the concept of general-domain cognition. Whether counting is domain-specific or a general-domain activity is strongly debated, with Gelman and Gallistel (1978) proposing that child's counting ability develops by domain-specific principles. This implies that the child does not use any general processing abilities. On the other side of the argument Shipley and Shepperson (1990) counter Gelman and Gallistel (1978) and hold that a child has a general ability to process discrete objects; this ability allows the child to identify what to count before he or she has the ability to count and that the ability to count also operates in some aspects of language acquisition.

If counting is a specific module and is impaired then that would have implications for the participants as non-functioning specific modules could lead to a permanent inability to use this processing module (Fodor, 1983).

Subitising

The original tests in this research were designed to ascertain the level of counting skills of the participants but before counting there is a more fundamental ability known as subitising. Subitising is arguably the most basic of number skills and is demonstrated at a preverbal level of child development (Feigenson et al, 2004).

Subitising is the ability to recognise the number of objects in a group without the need to count the objects (Chi & Klahr, 1975; Starkey & Cooper, 1995); this is believed to be groups of up to five objects for most adults. Initially this seemed to be such an innate skill that there was no intension to consider it as a measure of the number skills level of the participants. There are potential problems with testing such a fundamental preverbal ability, especially with the level of language skills of the participants; however, successful tests have been carried out with infants (Paterson, 2001).

The elements of subitising

The term subitising was first used in 1949 by Kaufman, yet the concept predates this in Freeman (1912) (Sarama & Clements, 2009). Several elements need to be present for there to be subitising; Saltzman and Garner noted speed in 1948 (Sarama & Clements, 2009), Jevons accuracy in 1871 and Taves confidence in 1941 (Sarama & Clements, 2009). Adults can recognise groups of objects up to the number three very rapidly (Trick & Pylyshyn, 1994) and groups of up to seven at marginally slower rates. Children demonstrate a slightly slower rate (Chi & Klahr, 1975); this may be

explained by the need for confidence, which many children lack at young ages. This was also a foreseeable problem with the participants, who would probably lack confidence, and required sensitive administration of any tests.

How subitising may work

There are two models of how subitising may work: the object file model and the numerical process model. The object file model relies on the premise that the brain recognises the shapes that the objects are arranged in (Glasersfeld, no year) and the numerical model that there is a numerical process that collects units (Meck & Church, 1983); both these models hold that subitising is a cognitive module. There are similar arguments on cognitive processing modules that apply to counting and this research project that also applies to subitising. There is a debate as to whether numerosity is a central process or a cognitive module (Butterworth, 2000), with Fodor (1983) contending that numerosity is a central process that has to be learnt. Butterworth (2000) meanwhile argues that the recognition of the small numbers 1-5 is so fast that numerosity cannot be a central process, and that it is in fact a cognitive module. There is support for Butterworth's argument as numerosity has been detected in some animals (Hauser et al, 2003), even fish (Agrillo et al, 2008). Support has also come from the theory of neuronal recycling (Dehaene, 2005); the implication is that there is a finite number of neurological processing pathways and that as species have evolved it has been necessary to recycle some of these processing procedures.

As most humans and many animals demonstrate the ability to comprehend some number concepts (Feigenson et al, 2004) it is argued that both

processes are used with different magnitudes of numbers. There are similarities in numeracy performance that are universal across number development and across different species (Feigenson et al, 2004). There is one process for representing large, approximate numerical magnitudes, numerocity, and another process for the precise representation of small numbers of groups of objects, subitising. These two systems explain human basic numerical understanding at an intuitive level, and are the foundation for the more advanced numerical concepts.

If the participants are deficient in any of these processes, whether module or central, they will also as a consequence not possess these number skills and then no amount of interventions will be able to overcome this. However, some research challenges these models of development (Paterson, 2001).

Methods used to investigate subitising

Research into the subitising skills of children with Down's syndrome and William's syndrome did not initially reflect the optimism shown by Sarama and Clements regarding the development of number skills in all children. The research found that the Down's syndrome group of children did not perform as well as groups of typically developing children that had been matched mentally and chronologically in tasks requiring the subitising of sets of two or three objects (Paterson, 2001).

How the tests were carried out

Designing a test for such a fundamental and preverbal skill for very young children is difficult but potentially could be adapted for this research. The

protocol that Paterson (2001) used to test for subitising used the basic Fagan apparatus. This apparatus is a portable viewing box, which allows the presentation of two visual stimuli at the same time; the box has a hinged panel, with two slots to hold the stimulus cards. The position enabled Paterson to see the infants' pupils clearly. In the centre of the box was a peephole, through which an observer, blind to the position of the stimuli, could see the visual fixations of the child. This was achieved by looking for the reflection of the stimulus on which the child fixated, in his or her pupil. The children were tested in a special child seat to keep them still and in the correct position.

The stimuli were coloured photographs and were presented randomly in pairs. Each pair was displayed twice, and the position of the cards was changed.

The child sat in the special seat and then the testing apparatus was brought to the child. A second researcher timed the child's looking at the left versus the right stimulus item by observing the corneal reflection of each stimulus in the child's pupil. A timer, which was set to five seconds, signalled when a trial was to end.

Paterson's premise

Paterson (2001) surmised that the children would concentrate more on the novel than on the ordinary. Therefore, she made the entire stimuli cards' subjects novel and only changed the numerosity; she expected that the novel numerosity of three would receive a greater level of concentration than the now familiar numerosity of two. Paterson (2001) found variations in her

subject groups, with the William's syndrome children demonstrating the greatest level of interest in the novel numerosities and the Down's syndrome children the least. This test would have been useful to test those participants with poor language skills and overcomes the problems of sounding confidence. However, it relied on a lot of equipment and two researchers to administer the test.

No link with adult ability

Paterson's other work in this study involved adults; her results and conclusions led her to question the current model of cognitive development for those members of society with learning difficulties. She found that performance in late childhood and adulthood is not predicted by the abilities of atypically developing infants. The two groups demonstrated different developmental trajectories for number understanding. The Down's syndrome children demonstrated problems with numbers that appeared early in the child's development, contributing considerable delayed development. In William's syndrome children one if not more of the foundations of number understanding functions as normal. She believes that problems for this group happen further along the developmental trajectory, or alternatively that a different fundamental building block for number does not function correctly.

She concluded that the results showed that developmental trajectories and developmental disorders are more complex than first believed and that an infant's cognitive profile cannot be inferred from that displayed as an adult.

Paterson's research into adults with Down's and William's syndromes showed that the Down's syndrome group outperformed the group with William's syndrome in the numerosity test (Paterson, 2001) and that the Down's group performed better in the numerosity test when the groups of objects were separated by a greater magnitude.

Cognitive domains are different for adults and children

Paterson (2001) concludes that the current mode of cognitive development may be flawed. That the impaired cognitive domain is the same in adults and children is not supported by the findings in her study:

> … these results suggest that neurodevelopmental disorders should not be thought of in terms of impaired and intact cognitive modules, present at birth. Instead, the data highlight that very different outcomes can arise from similar starting states (as illustrated by the vocabulary data). It is also possible that different starting states can result in similar outcomes. Atypically developing infants with different syndromes follow different developmental trajectories, so it is crucial to study the process of development and not merely to make assumptions using data from the end-state. (Paterson, 2001)

The conclusions of this research have important implications for number development in infant learners with impairments. As the adult end-state is not a good indication of where the infant is struggling to develop his or her number skills a more flexible and informed intervention strategy is recommended. An intervention strategy that looks at the strengths and weaknesses in adulthood to inform the teaching in children will, Paterson argues, potentially miss key developmental stages, as the impaired child's developmental trajectory differs from that of the typically developing child.

These conclusions had implications for the interventions in this study. It did not necessarily follow that what was taught at school and had not worked would not work in adulthood. Therefore, it opened up a broad field of possible teaching interventions that could be used.

Ordinality and ordinal numbers

Cardinality, counting, numerosity and subitising are all basic number skills. Another basic concept that needed to be considered was ordinality and ordinal numbers.

Ordinal numbers play a different role from cardinal numbers in basic number skills as they describe the position in a sequence: first item, second item, third item, etc. They too are important in everyday life; their use in the world of sport is obvious, but ordinal numbers are also used in daily situations. Directions are often given using ordinal numbers – 'the second turn on the left' and 'the fourth bus stop' – and in forms of rebuke – 'that is the third time I have told you; I won't tell you again'. These are potentially a use of numbers

that adults with learning difficulties can use in a fragmented way, as the example with the number 55 bus. Full mastery is not necessary; the part skill can still be useful in everyday life.

Only thinking of numbers as ordinal when they are described as ‘first’ rather than ‘one’ or ‘tenth’ rather than ‘ten’ is a restrictive concept as for example ‘aisle 5’ is no less ordinal than ‘the fifth aisle’ (Sarama & Clements, 2009). These examples, however, do rely on a knowledge of and ability to use counting; if you cannot count to four you will not find the bus stop and if you struggle with two you will miss your turning.

With ordinal numbers the English native language child has to learn different number words associated with this concept; first for one, second for two etc. Again, as with cardinal numbers, your native language has an impact on the ease of your ability to master the ordinal numbers. Chinese speakers tend to develop much quicker understanding, as the Chinese ordinals require the addition of ‘di’ to the cardinal number (Miller et al, 1995). However, the ease of acquiring the ordinal number words in this way may actually delay the understanding of the two different number concepts. Chinese children take longer to grasp the difference between the concepts of ordinal and cardinal numbers. The different words used by English-speaking children can give them an advantage; as they struggle with the different names and are forced to think earlier of when and why to use them they are exposed to the differences every time they are used (Miller et al, 1995). The development of learning ordinal numbers is more complex than of just learning the number words and is possibly closer to learning to count on (Miller et al, 1995).

Another ordinal number conundrum faced by children is that one ordinal number does not necessary relate to just one cardinal number. For example, the *first* number after twenty-two is not *one* but twenty-three. In this case *first* relates to twenty-three, not one, which a novice may think. This demonstrates the need to be able to count on and add or subtract, as in the problem 'what number is the fifth *before* twenty-one?'

There are of course other forms of ordering in our everyday lives that do not require the use of numbers, including the days of the week and months of the year, which are all ordered sequences. However, these sequences are finite and demonstrate the advantage of using numbers for ordering as there are an infinite number of positions in the sequence and not just seven or twelve as in the cases of the days of the week or months of the year, respectively.

That ordinal numbers are so closely linked to learning the words and the subtle difference between cardinality and ordinality could pose great demands on the participants and could be used to determine their level of numeracy skill.

Ordinality

Ordinality is the concept of greater than and smaller than. Ordinality has much in common with ordinal numbers in that ordinality is again ordering in sequences, not in a numerical order; it is about recognising size and ordering by amount. The components required to be effective at ordering require the ability to compare and for larger numbers of objects the ability to make reasonable estimations.

There is evidence that a typically developing child can understand ordinality at an age as young as eleven months (Brannon, 2002) and that these children can also understand bigger and smaller in terms of capacity. This may be an easier task than dealing with counted amounts as when comparing sets through counting the number in the first set has to be remembered as the second set is counted and then the two numbers compared (Sarama & Clements, 2009). There are many opportunities to make a mistake in the counting process. The ability to use subitising and numerocity effectively is clearly necessary at whatever age you are (Ansari et al, 2005).

Although there is evidence that three-year-olds demonstrate the ability to recognise equivalence or non-equivalence in similar items (Mix, 1999), it has been found that three-year-olds did not use an analogue number magnitude or object-file mechanism to compare numerosities, as was expected (Rousselle et al, 2004). This indicated an understanding of cardinality in the development of numerosity understanding.

Counting and cardinality are also implicated in sequentially presented objects, a skill that is developed much later (Mix, 1999) and seems to require some form of counting.

This would imply that those participants with poor counting skills will also demonstrate poor ordinality, and that the development of basic counting is a prerequisite to mastering ordinality.

There is much research into how children use counting to compare sets of objects (Sarama & Clements, 2009). There is, however, reluctance by many

children to use counting as a form of comparison (Sophian, 1998). Suggestions for why children demonstrate this reluctance ranged from the idea that the children did not understand the relevance of counting (Sophian, 1998), that there is insufficient available memory (Pascual-Leone, 1978) or that children believe counting is too difficult and in their experience unreliable (Cowan, 1987). Others suggest that children do not like using counting in a new and novel situation and that the confidence to do this only comes later (Steffe et al, 1983).

For children to use counting effectively to compare sets they need enough memory capacity to store the result of the first count as they count the second set. Also, they require good reliable counting skills so they can be confident in their answers. This obviously takes time and is built on the successful use of the strategy. It therefore explains why this skill is slow to develop (Sarama & Clements, 2009).

Numerosity estimation

When ordering there are innumerable estimation techniques that can be used; of interest here is estimation through numerosity. The research appears to view estimation through numerosity of set size as a novice strategy that is dropped as soon as a more advanced arithmetic-type strategy can be adopted (Luwel et al, 2005). Earlier studies (Hecox & Hagen, 1971) found encouraging evidence of children aged five to eight being able to estimate numerosities successfully, but the lower ages found some difficulties. This is surprising when one considers the level of subitising and counting skills demonstrated at younger ages.

Using the available research Sarama, Clements and Brade (Sarama & Clements, 2009) created an age-related developmental learning curve for numerosity estimations. The trajectory started with a pre-estimation stage, where counting was used and no estimation, then wild guessing and then a transition to spatial extent. At this stage the children did not use wild guessing but some counting, yet showed no understanding of small or large numbers (Sarama & Clements, 2009).

As the child's age increased more sophisticated strategies were used, but the success was always dependent on the child's proficiency with any particular technique rather than age alone.

Sarama and Clements (2009) concluded that numerosity estimation may depend on highly developed numeracy skills, and when the child is operating outside their experience they struggle to be successful. There appears to be a direct correlation between number words and numerosity (Lipton & Spelke, 2005). This has important implications for the need to develop the length of the word sequence used in counting.

Implications for this research project

There are two main themes from the literature that could have affected this study: how the brain works and whether the processes involved are modules or central processes. The other theme is whether it is possible to work out from knowledge of the developmental trajectory where the learning of the number skills has not been fully mastered.

The two conflicting views of the processes involved have a bearing on what type of intervention should be taken and when. I would have been encouraged by Paterson (2001), who felt that there is a flaw in the connotative development model. I would also reverse her own argument that the adult end-state does nothing to inform us of how to teach the child: neither does teaching through childhood necessarily mean the end-state cannot be changed in adulthood. If key development stages were missed they may be learned at a later stage.

Any problem with the developmental trajectory should be identified and with this knowledge it should be possible to correct any deficiencies if the cognitive processes allow these functions.

Chapter 2

DESIGN

Introduction

This chapter will describe the research method used to investigate the research question. It will also relate how a different approach was attempted initially and why that research design could not be carried out. This forced change challenged previously held beliefs and new truths for the researcher were developed to enable the research to take place. This chapter will briefly describe the initially held intellectual prejudicial stance that the scientific method was the only method and that empiricism was the only truth. The chapter records the realisation that other epistemology truths have value and the implication that research based on these epistemologies must therefore have value. This chapter will describe the development of the researcher's realisation and re-evaluation of the intellectual worth of the action research cycle and consequently how it became the adopted research method. It will discuss the practical issues of validity and the ethical challenges of research in education and how this research met these challenges.

Wider framework

This action research project is driven very much by the belief that research can and should change the methods and ways in which we carry out our

everyday teaching for the benefit of the learners. For this to lead to an improvement in the participants' lives, as the participants are adults with learning difficulties, these changes should be liberating. This research is a refection of how methods used in teaching number skills in a further education college are carried out and what action can be taken to improve these methods. It is intended as emancipatory research or reflective action (Wallace & Poulson, 2003) and sits within the typology of research interests as an emancipatory interest (Habermas, 1971).

The intention is to examine common practice within this further education department and challenge the views of the teachers, carers and parents of the participants to create a critical research domain (Gunter & Ribbins, 2002).

Epistemology

My understanding of what constitutes knowledge has fundamentally changed over the course of my study and research. I was forced to abandon my long-held view of the scientific method and empiricism and to embrace a more constructivist epistemological stance.

Changing epistemologies

Changing one's epistemological understanding is not unusual or unique; Perry (1968) plotted the changes in the understanding of truth of undergraduates. This research revealed that undergraduates moved from a naïve belief that knowledge is certain and unambiguous and developed through stages to a more sophisticated stance that knowledge is not constant and is often tentative. Perry's work received much support (Baxter Magolda, 1992; King

and Kitchener, 1994); however, Schommer-Aikins (2004) disputed the findings and argued that personal epistemological beliefs are more complex than these models would suggest.

Another challenge to his study came with a more female-centred approach that considered this as a male model of epistemological development and suggested that women go through different stages of understanding (Belenky et al, 1986).

Both male and female routes to epistemological maturity appear to lead to a form of less certain epistemological reality than a positivist scientific stance. It was necessary for me to undergo this change in my understanding to allow me to carry out the type of research method required to investigate this research question.

My journey took me from theories of knowledge that stressed its absolute, permanent nature towards theories that put the emphasis on its relativity or its dependence on the situation in which the knowledge is gathered. As the research method moved towards action research and away from a controllable set of variables this move was necessary. As my confidence and experience increased and as I was exposed to different epistemologies I became more comfortable with contradictory knowledge realities. Research into undergraduate epistemological beliefs (Whitmire, 2003) would suggest that many students demonstrate this level of adaptability. Some of today's learners display a far more sophisticated way of understanding knowledge, yet the majority still demonstrate a high level of naïvety (Stathopoulou and Vosniadou, 2007).

It became apparent that there was a progression towards an epistemology of continuous development or evolution, and how the gathering of truth changes the very truth that is being sought. The trend in epistemological understanding was from a static, passive view of knowledge towards a more adaptive and active one.

Positivism

My own beliefs came from scientific training and a positivist model of truth; this stance is best described in Kantian terms as a belief that ‘categories’ exist that are generated by innate understanding and ordering of the sensually perceived information. This view of knowledge appears to be similar to those of many, if not most, science and engineering graduates; they hold implicitly that positivism is the only form of truth (Domert et al, 2007).

In a Kantian framework there is an absolute truth, which can be known or can be approximately known through the senses. For those things outside experience Kant introduced the concept of ‘Ding an Sich’, the thing itself defined as unknowable though certainly existing (Guyer, 1987).

This argument is an attractive one to the scientist and engineer who supports and is supported by the scientific method. However, not all scientists support this epistemology and are willing to exposes the shortcomings of scientific

epistemologies. Maturana (1978: pp. 28-29) states:

> … specifying the operations that he or she can perform determines the observer's domain of possible observations. … because only those statements that we generate as observers through the use of the scientific method are scientific statements, science is necessarily a domain of socially accepted operational statements validated by a procedure that specifies the observer who generates them as the standard observer … In other words, we are not usually aware that science is a closed cognitive domain in which all statements are, of necessity, participant dependent, valid only in the domain of interactions in which the standard observer exists and operates. (Maturana, 1978: pp. 28-29)

The scientific method relies on being able to control the variables that are not being investigated; this can often be difficult in a laboratory but is almost impossible in a classroom. The scientific method does not lend itself well to classroom research; in the messy real-life (Cohen et al, 2007) environment of social science the subjects' feelings, interactions and daily life make it impossible to control the variables.

To move forward it was necessary to abandon any belief in positivism as the only truth and to adopt a more realistic epistemology that suited a small-scale action research study. Maturana opened the door to this possibility; clearly he believes and gives a powerful argument to the view that positivism is actually constructivism.

Pragmatism

The work of Ann Brown and design-based research, suggested a more appealing and palatable step on the epistemological journey; for someone emerging from a restricted science background, it eased the transition to constructivism. Design researchers use the epistemology known as pragmatism (Biesta & Burbules, 2003). The pragmatists were looking for solutions to real-life problems, and as the name suggests were pragmatic in their approach, choosing from a range of approaches that they deemed would produce the best solution. The early pragmatic movement was dominated by Charles Sanders Peirce, who attacked the ontology of the 'experimentalists' and their scientific method and also the 'metaphysics' of 'Kant, Berkley, and Spinoza'. He developed the idea of a different epistemology and ontology and defined the pragmatism doctrine as:

> Consider what effects that might conceivably have practical bearings you conceive the object of your conception to have. Then your conception of those effects is the WHOLE of your conception of the object.
> (Peirce, 1905: p. 169)

Peirce perceived pragmatism as a doctrine of meaning and therefore truth through consequence. You conceive of a consequence and this becomes true only if it actually happens, hence truth is a process and can only be tested in the future.

This was a very appealing epistemology as it appeared to make the end result of the research and the interventions resulting from the research the measure of truth. Any outcomes that positively affect the participants' lives, how emancipatory the research had been and the effects on those taking part will be the measure of truthfulness.

Pragmatism has a long association with education research and reform and the liberating possibilities of pragmatism have long been recognised. The educational reformer Dewey had adopted a form of pragmatism and applied this to developing non-elitist universal education (Koschmann, 1996). Dewey believed in greater public participation and a move from the avant-garde; he believed in an emancipatory approach to education research. He attempted practical change with George Herbert Mead, in their Laboratory School in Chicago in 1902, applying their particular brand of pragmatic instrumentalism.

Dewey himself rejected the term epistemology and used instead the terms 'theory of enquiry' and 'experimental logic', both terms reflecting Peirce's view that epistemology was a process rather than an object. These terms were again very appealing as they stressed the inquisitive nature of seeking knowledge and the need for rational analysis.

Dewey described four phases to the process of knowing: firstly, there is a mismatch of cognition of what the 'object' is and what the 'object' is expected to be; secondly, the process of 'conceiving' the facts relevant to the object; thirdly, reflecting on the cognitive elements of the correcting the mismatch; and lastly, testing the supposition (Dewey, 1903).

Pragmatism is knowledge as problem solving. Does the 'truth' work? If so it is the truth. If the model works then it is the truth. Dewey's instrumental pragmatism was criticised by his contemporaries (Shook, 2000). They claimed that the object and the observer must be separated. Dewey counterclaimed that knowledge of the object separated from the observer was not knowledge.

However, Garrison (1995) asserts that many social constructivists were attracted to Dewey's particular brand of pragmatism and argues that educational researchers have often overlooked this epistemology. In championing Dewey's pragmatist epistemology Garrison exposes Dewey to the same criticisms that are levelled at the constructivists, that there is a risk of creating one's own truth. This concerned me but Maturana had made the same criticism of positivism; I was aware that I may be guilty of creating my truth to suit my needs.

That the researcher decides whether or not the solution works and the problem is solved remains a potential flaw. There are claims that Dewey's pragmatism is qualified relativism (Thayer-Bacon, 2002). While responding to McCarthy (1996) Thayer-Bacon claimed that McCarthy was attempting to 'rescue pragmatism from an association with relativism' (p. 91), a desire born out of the increased criticism aimed at relativism. She argued that although Peirce's ontological realism exempts him from the accusation of being a relativist, Dewey does not adopt the same ontological stance exposing him to the accusation of being a relativist.

Relativism is much criticised, partially as it would appear that it allows any truth to be true and can generate any 'useful fiction' (Osborne, 1996) as the

truth.

The appeal of pragmatism

An appealing underpinning logic can be found in the pragmatic epistemology: that knowledge consists of models and that no model can represent all information. This pragmatic logic implies that even if a complete model did exist, it would be too complicated to use in any practical way. Models are developed to represent the world in such a way as to maximise solving problems. This will produce the paradox of contradictory models existing at the same time; however, the pragmatist approach is to accept this and choose the model that solves the problem as accurately and simply as possible. For the pragmatist the 'Ding an Sich' is a meaningless concept, just solving the problem. Consequently there is an element of trial and error in finding the best fitting model that reflects the real-life processes often used in the classroom.

To an educational researcher there is an obvious appeal in pragmatism as a useful epistemological stance. Not only does it address the practical need to define what truth is but its historical place in emancipatory research is also attractive. I had come to realise that not all premises could be tested by the scientific method, which was also potentially a constructivist reality, thus echoing Maturana's claim that even empiricism is a construction of the observer and culture.

Pragmatism solves the problem of epistemology by creating truth as a test of validity; the test becomes 'does it work or is the problem solved?' If it does not solve the problem, then come up with another truth that does create a

solution. It overcomes the validity question posed by adhering to the scientific method standpoint; as repeatability and controlling variables are no longer necessary if the problem is solved on an individual scale then it is true for that given situation, and universality is not so important.

This realisation was extremely liberating and allowed me to pursue this research comfortably.

The question moves from one of truth onto the integrity and morals of the researcher. Wicks and Freeman (1998) champion pragmatism as a solution to the positivist and anti-positivist debate in the field of organisational studies as unlike positivism it does not claim to be value neutral but is reliant on a strong ethical stance. Educational research also needs an epistemology with a convincing ethical base.

Research strategy

A desire to carry out a form of emancipatory research drove this research project and the need for a particular problem. The topic that was of interest was numeracy and adults with learning difficulties. The emancipatory possibility of improving the lives of adults through effective maths teaching was attractive. The possibility of liberation from formal maths tuition and replacing this with more practical solutions for an enhanced life seemed a desirable goal.

It was initially felt that a mixed methods approach would be the most effective; a baseline test and its comparison with an exit test would generate a form of quantitative data. The intervention stage would generate both quantitative and

qualitative data as an attempt to assess what was working well as an improved teaching strategy was experimented with. This reflected the changes in attitude to what is truth; the ability to accept qualitative data as valid and not mere opinion showed an acceptance of the value of a pragmatic epistemology.

The intention was to explore the emancipatory possibilities by investigating a sensitive age in number skills development similar to the sensitive age in language development (Curtiss, 1977; Taylor, 1990; Akmajian et al, 1992; Locke, 1994a; 1994b; 1997; Li et. al., 2007). It soon became apparent that this was far too ambitious in terms of time, resources and the developmental capacity of this researcher.

By scaling down the project to one of a local study the possibility of successful intervention became more probable. The chance of improving some of the participants' lives became an attainable goal.

Research methodology

The search for a sensitive age

The initial interest was, and remains, in adults with very low mathematical ability. At this initial stage the work of Butterworth was of great influence and there appeared to be a gap in the research that explored numerosity and a sensitive age. Numerosity is viewed as a fundamental element of mathematics (Sarama & Clements, 2009); it is the ability to recognise the number of objects in a group without resorting to counting. A sensitive age is a concept accepted in language development (Locke, 1994a).

Initially the intention was to investigate any parallels between number and language development and particularly a critical period that if missed impacted adversely on developing number skills.

The available work on language and feral children (Curtiss, 1977; Taylor, 1990; Akmajian et al, 1992) confirmed that these researchers believed that there is a critical time for language acquisition. However, these researchers were working with a small, peculiar, distinct group of participants and there are obvious problems with extrapolating these results and generalising them to the population as a whole. Feral children have complex social and emotional issues connected with their particular situation and it is extremely difficult to distinguish these issues from their problems of language acquisition (Rymer, 1993).

Support for a critical or sensitive period could be found with other researchers; Li et al's (2007) work in the United States with Chinese and Korean immigrant children demonstrated a linear relationship between the age at which children arrived in the US and their proficiency in the English language. Locke's theories (1994a; 1994b) on language development clearly support this. Locke (1997) proposed four phases of language development, each building on the previous phase. If Locke's model is correct then any lack of development of the second phase will permanently impair the development of language and may correlate with a sensitive stage. This stage was initially believed to be associated with puberty (Lenneberg, 1967); however, Locke (1997) claimed that research evidence indicates birth to six or eight as being critical with a continued transitional decline to adolescence.

Initial research plan

In the attempt to investigate numerosity in children with learning difficulties several local special schools were approached. Dealing with these schools was more problematic than had been anticipated; there were several obstacles to overcome:

- The curriculum did not allow children to be taken out of the 'numeracy hour' to receive non-national curriculum mathematics.
- A class at lunchtime was seen as impossible as it would interfere with the daily routine and the children's lunch.
- Before- or after-school sessions were a possibility if I could arrange for the children to be transported independently to or from school with an escort.

It became apparent that this research to investigate the numerosity of children or a sensitive period was not going to happen in the limited time that was available.

It was impossible to find a local school that was willing to forgo any part of the national curriculum (QCA, 1999) to allow the development of any teaching intervention during the school day. The National Numeracy Strategy had to be adhered to and so did every other hour on the timetable. After-school lessons were possible if negotiation with parents allowed for transport home and this was not forthcoming. The teachers and heads acting as the gatekeepers of knowledge (Porter & Lewis, 2004) were, if not keeping the gate closed, making it difficult to open. It would be simple to see them as obstructive;

however, this would be harsh and disingenuous. In truth they were interested and wanted to help. However, they felt that the demands in implementing the national curriculum restricted their flexibility and hence they could not accommodate this research project.

On reflection this proposed project was far too vast and the method proposed far too limited to investigate the issues. Other possibilities involving the deficiencies in the learning trajectories of adults with learning difficulties involved in learning numbers were probably of equal importance (Paterson, 2001).

Although frustrating at the time, the changes were liberating and empowering; they required the investigation of other research methods and broadened the understanding of what was possible. It was necessary to search for a new research method to match the scope of what was possible yet still true to the desire to be emancipatory. This search is what initially led to the design-based research method and pragmatism.

Connecting educational research to the classroom

In 1992 Brown's 'Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings' espoused a view that educational research was too divorced from practical application in the classroom and there was a need to bridge the gap between the laboratory and the classroom. She proposed an approach to educational research based on an engineering paradigm, where ideas and teaching methods should be tested in the classroom as well as in the laboratory to see if they work. This

was an appealing stance as it was within the spirit of Dewey, who had the desire to take the research from the ‘avant garde’ and also allowed teachers some control of the research within their classroom yet still valued the work of the researchers.

Brown created design-based methods (1992), a fusion of laboratory-based research and the classroom; design-based methods use techniques and teaching tools developed in the laboratory then synthesise and refine them in the ‘real-world’ classroom with real teachers and real learners.

In order to call this research design ‘design-based’ and to be true to the pragmatists and Brown’s vision it would have been necessary to develop teaching tools in the laboratory to support the interventions: apparatus such as computer programs, games and teaching tools developed in a controlled setting to aid the intervention strategies. There is a need for these processes to be prepared away from the messy nature of the classroom with its innumerable variables, to help establish the effects of the interventions before they can be tested in the real learning space.

There was neither the time nor the facilities to undertake this for this research project. It was felt that it would be wrong to stretch the concept of this design and to call the research design-based when it was so distant from Brown’s original criteria. Another just as valuable research design was available and required no compromise: action research.

Action research

The desire to use innovative techniques in the classroom, the underpinning pragmatic belief in knowledge and the aspiration to have a positive impact on the participants and their lives are not solely reserved for design-based methods.

These values are also championed as fundamental to action research design, another powerful and useful design method to investigate and solve local and individually particular problems. Ferrance (2000: introduction) states:

> … action research allows practitioners to address those concerns that are closest to them, ones over which they can exhibit some influence and make change.

For those interested in emancipatory research at a local level this design method is attractive as a defining feature of action research is change and responding to change (Ferrance, 2000).

Carr and Kemiss (1986: p. 162) gave the following definition:

> Action research is simply a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out.

This definition helps to validate small-scale research, such as the type planned in this project, based in the working environment; it has become a

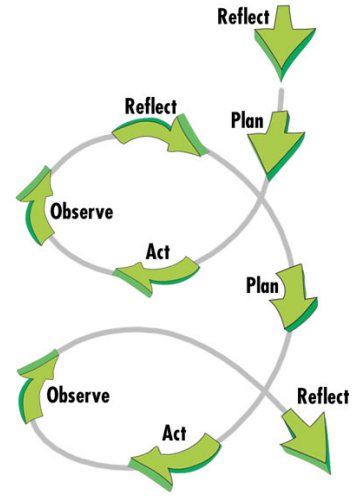
credible form of the educational establishment. Action research as a post-positivist paradigm is particularly well suited to research that involves humans and not just objects (Robson, 2000).

Historically action research has broadly fallen into two main fields: one of social welfare and one of education. In the social welfare context the aim is to bring about social change and right social wrongs and injustice. This builds on and follows the work of the man attributed with originally developing action research Kurt Lewin, in 1948.

The other strand of action research is one used in an educational setting where teachers ask their own questions to solve their own localised questions (Carr & Kemmis, 1986).

The cycle of action research

Besides the localised and the participatory nature of action research, a major defining characteristic is the action research cycle; the action researcher engages in a spiral or cycle of questioning, reconnaissance, planning, action, evaluation, amending the plan, action and so on (Lewin, 1946).



(deet, 2008)

Following the Action Research cycle or spiral the researcher must reflect on the issue, plan the research, execute the research, observe the results of the research, reflect again and continue until a satisfactory resolution is reached.

However, McTaggart (1996: p. 248) warns against just following the cycle and is often quoted:

> Action research is not a 'method' or a 'procedure' for research but a series of commitments to observe and problematize through practice a series of principles for conducting social enquiry.

It is argued that the cycle resembled the work of Dewey (Smith, 1996), thus making it attractive both in epistemological and in emancipatory terms.

Action research medium of change

Post-1960 action research has become viewed as a specific type of small-scale practitioner research project (Gustavsen, 2001). The response to

change is one of the main purposes and strengths of this form of action research (Carr & Kemmis, 1986). By stressing the importance of change and improvement in teaching practice there is a danger of a shift away from Lewin's (1946) initial protocol of a cycle of planning and acting, and recording and reflecting.

Criticism of action research

There are criticisms of action research, that it lacks rigour (Atkinson & Delamont, 1985), that the local conditions, schools, are so socially complex that those engaged in the research are unable to unravel the necessary issues and critically reflect upon them (Popkewitz, 1984) or that it is too parochial (Baskerville & Wood-Harper, 1996; Adelman, 1984). The method has been viewed as being of poor quality and lacking validity, relying on one practitioner or a small group of practitioners to conduct particularly localised research (Adelman, 1989).

In defence

In contrast, Borda (2001) is robust in his rebuttal of these arguments and calls for practitioners to be rigorous in their design and their data analysis to help counteract any possible criticism. He claims a direct developmental line to the early scientific practitioners Bacon and Galileo and their desire to apply their research discoveries practically in the real world. He claims that not only does effective action research have validity, but it also has greater worth, as good action research is emancipatory and empowering to all the participants. Borda is passionate and persuasive in his arguments; it is easy to be swept away by

his enthusiasm. His ideas are attractive to liberal-minded educationalists who believe that education, and hence educational research, is a force for social justice. Good practitioner research relies on an ability not only to be self-reflective but also to be self-critical; from this comes good action research design. Arguably it is a design method that exposes the practitioner to real self-scrutiny, which creates a need for bravery; how willing can you be as a practitioner to have your work exposed to scrutiny, or even self-examination?

Action research: a tool for democratising research

Supporters of action research champion the fact that it democratises research (Chambers, 1983; Laidlaw, 1994), echoing Dewey's desire to remove research from the 'avant garde'. Action research takes research out of the hands of the academic elite who have the necessary support structures to work on larger-scale projects and provides opportunities for small localised problems to be addressed by teachers and school management (Chambers, 1983; Laidlaw, 1994). It also answers any question on the value of the results and how the results can be used effectively. Unlike some large-scale macro research projects that require changes in public policy or by large institutions to have any impact, the small-scale results are more readily shared with the participants. They can be used and acted upon at the local level. This is not to say that the findings generated by action research are only valid locally; the results will benefit equally from the processes of scrutiny through publishing, peer reviewing and being exposed to a wider audience. Broad exposure helps address any validity issues and the dissemination of findings may help others

in similar situations; very few situations are so unique that they cannot be adapted and adopted by someone else.

However, there are questions regarding the truly egalitarian claims of action research. Altrichter (1993: p. 53) states:

> … that its attractiveness to innovative, professional teachers repels at the same time less innovative, less professional teachers. Thus action research is in constant danger of elitism and being the hobbyhorse of an 'avantgarde' who lose sight of the 'average people'.

He does, however, fail to suggest how to involve these less innovative teachers in action research or any other form of research. This criticism in itself does not devalue action research or those who undertake it. Accepting that action research does not empower or motivate every teacher to become involved in formal education research is recognising that all teachers are different and have diverse reasons for being in the profession.

Lack of rigour

A far greater threat to action research being viewed as a legitimate form of research than the lack of inclusivity and Altrichter's criticism over elitism is the perception that it lacks rigour (Isaac & Michael, 1987; Applebee, 1987; Toulmin, 1982). Educational action research has been through trying times and became unfashionable, viewed as unprofessional and amateurish (Kemmis, 1993).

Lack of validity

What makes action research appear amateurish and lacking in rigour is the apparent lack of validity, due in no small amount to the level of subjective interpretation of the events available to the researcher. This can potentially arise as a major fault with the cycle itself and some researchers may make fundamental errors with the basic cycle (Elliott, 1991). These researchers fix their initial idea and therefore it is not open to revision. As a result reconnaissance is used to find facts to support the original idea and actions that will solve the predetermined and fixed problem. There is no cycle, no reflection and no review, just a self-fulfilling operation that by design will be 'successful' but successful in a self-limiting manner where the results are of questionable quality.

To overcome any attacks on the validity of action research there are some useful suggestions to the action researcher (Feldman, 1995).

Elliott (1991) suggests that the practitioner researcher should:

- use monitoring techniques to give evidence of how effectively the action is being implemented
- gather evidence of unintended effects
- use different techniques that enable different perspectives to be considered

Altrichter et al (1993) add:

- checking against others involved in the research for alternative viewpoints
- practically testing the practice and results
- ensuring the research is ethical
- ensuring the research method is of practical use to other practitioners

The intention was to incorporate these suggestions into this research project to give it rigour and validity, through reminders of the need to be vigilant with regard to subjectivity and conversations with the supervisors.

Action research strengths

The strength of action research is to answer local questions at a local level, not necessarily to influence general policy or even add to the general body of knowledge. To undervalue this research because it does not match the style or protocol of more elitist models is to deny action research's provenance, developed as a tool for social reform (Lewin, 1946). Action research fulfils a different yet equally important role from other forms of research: action research investigates local issues and generates local solutions. It is not restricted to the laboratory; it is practical and classroom-based and merges generalised educational knowledge with specific small problems. In this way it is very relevant and important to the local area being investigated. Curry (2005: p. 2) uses Gustavsen (2001) to make the case clearly for this strength

of action research when she writes

> I prefer the characterization of Bjorn Gustavsen … who called action research the 'mediating discourse' between the two often isolated discourses and professional communities involved in theory and practice.

The relevance of action research is based on the local solutions it produces, and on those involved in the research.

Any initial scepticism of action research as a suitable method had been overcome and the arguments that this method is any less valid than other forms of research had been rebutted; it is all a matter of ethics, honesty and rigour.

In conclusion action research is a valuable method of research, and it is identifiable by the cycle of reflect, plan, execute, observe and reflect. It is small scale, participatory in nature, includes those it affects and deals with local problems. This became the new starting point; the value of action research had been affirmed as useful to those who require a practical and an emancipatory research method (Elliott, 2001; 2007; Carr & Kemmis, 1986).

Adopting and adapting to action research

It was clear that action research would be a sensible method to investigate and explore the research question. To recap, initially the interest in numeracy had been prompted by many requests by parents and carers to improve their child's or charge's ability with money. This forced the reply that the learner's

fundamental numeracy skills did not allow them the ability to deal with money effectively. The learners would often have no concept of ten or one hundred, suggesting that they would not have the ability to use coins; especially as the coins follow no logic in size to represent the value. The value of our coins is still reliant on the concept of copper being worth less than silver, which in turn is worth less than gold, even though our coinage has very little of these metals left in it now.

The desire was to know whether the teachers, the learners, the college and everyone involved were wasting time, energy, hope and resources attempting to achieve the impossible and to teach number skills to those who would never gain them. Through discussions with colleagues the research question became 'whether innovative teaching interventions can improve the development of number skills in adults with learning difficulties. Furthermore, if no amount of intervention will have an effect, can practical non-number-based strategies be developed for use in everyday life to overcome any number deficiencies?'

If the answer to the first part of the question is yes, then there are several positive implications for the learner and further education provision:

- The quality of life for the individual will be improved (Snell & Brown, 2000)
- A case can be made for access to further education colleges, even under the restrictions of the white paper (DfES, 2006)
- A role will exist for a specialist: one who understands the fundamentals of counting to identify specific errors and develop an individual learning

plan for the learner who will have a high expectation of individual success (Boutskou, 2000)

- There will be an opportunity for lifelong learning (DfES, 2006)

If the answer is no, there are still potential positive outcomes as valuable learning time can be used more profitably, rather than wasted in an attempt to develop a skill that the learner cannot master. This learning time can be more effectively used to teach skills that enhance the life experience of the learners. It will also require a more creative and imaginative concept of numeracy provision for these learners (Lee & MacWilliam, 2002).

Action research was a good method to adopt as the project was local, dealing with a small number of participants and each session would require reflection and analysis. There was a real opportunity for an emancipatory effect on the learners attending the special education department of the further education college. Armed with good data it would be possible to sway the curriculum design and convince the staff team.

Working in my own teaching environment

There were several advantages to working with this group of learners: I had already established a level of trust with the teachers and management and they had some concept of what I was attempting to do. Through this familiarity, gaining the consent of the carers was not problematic; this is not always the case (Porter & Lewis, 2004). I had also gained a level of trust and authority given to me by my position within the organisation and this made gaining the consent and co-operation of the learners less problematic. As

there is no set curriculum for post-16 there is greater flexibility in both the timetable and curriculum within the further education sector than within the school sector. This enabled the intervention work with learners to have a reduced impact on other parts of their learning. Although the research fitted many of the design features of the action research model, the use of the 'cycle', being a teacher–researcher manager study had a flaw: the participants had little say in the design other than that they were quite willing to give up their lesson time to join in.

As this was a small group of only eight learners it was potentially restrictive; they attended college only three days a week and the sample was small. It was therefore necessary to use the group as its own control by testing the learners then waiting for a period of time to lapse then carrying out the pre-intervention test. For validity this period should match the time over which the intervention would take place. It was possible to use four learners as subjects.

By abandoning the initial design and research question, by choosing a more manageable-sized project and using my place of work, the first step had been taken in the action research cycle.

Ethics

Good action research is fully inclusive of the participants. In good action research participants are involved in negotiating the form the research will take; its supporters claim that in this regard it is uber-ethical (Altrichter, 1993). However, this could be viewed as merely another type of informed consent

where the power relationship between the research–teacher and the participant still plays a major role.

The Nuremberg code

Acceptable research today is shaped by our societies' current views and past experiences of research. The research ethics of today appear to reflect the view that the weak and vulnerable need to be protected from the strong and powerful, as embodied in the Nuremberg Code (1947). The Nuremberg Code attempted to codify how ethical research on human participants should take place.

Principle 1 states:

> The voluntary consent of the human participant is absolutely essential. This means that the person involved should have legal capacity to give consent; should be so situated as to be able to exercise free power of choice, without the intervention of any element of force, fraud, deceit, duress, overreaching, or other ulterior form of constraint or coercion; and should have sufficient knowledge and comprehension of the elements of the participant matter involved as to enable him to make an understanding and enlightened decision.

Education is somewhat behind in evaluating its ethical code as medical research revaluated its ethical code in the 1960s in light of the criticism from Beecher in a series of papers culminating in 'Ethics and clinical research' (1966). In this paper Beecher illustrates unethical practice in medical research

and shows that there is a need for constant vigilance. Beecher argues that an unethical experiment cannot be made ethical after the fact. Burgess (1982) argues that the field of education research lags behind other fields in adopting a code of ethics partly due to the lack of scandals.

Voluntary consent; making an 'enlightened decision'

Research communities rely on the principles of personal choice and voluntary consent in overcoming one of the ethical dilemmas of how researchers can protect the weak and the vulnerable. This principle of voluntary consent, the cornerstone of medical research, has become the main principle of subsequent ethical codes used by other humanities and social science disciplines in their associated fields of research.

Although researchers should remain vigilant and adaptable to changes in social values they should also take a role in shaping and forming these values. By stating clearly what is and what is not ethical in research, social science researchers not only guide and moderate each other's conduct but also help to develop society's accepted ethical norms. The setting of these standards has seen the adoption by social science research disciplines of research ethical codes of practice.

The BERA code and my ethical stance

The guidance was originally drawn up 1992 as the *BERA Ethical Guidelines* and revised for use in educational research in 2004. The need to change the guidance so soon does not necessarily demonstrate that there were perceived inadequacies in the original guidance but reflects a desire to adapt

to current trends in educational research. Two of these trends were specifically identified in the aims of the revision, which were to address the

> … academic tensions that a multi-disciplinary community generate
>
> … Secondly it seeks to include the field of action research. (p. 4)

The education research codes go beyond just protecting the weak and vulnerable and aid researchers in addressing other areas of potential unethical behaviour. Therefore, potentially problematic areas that were identified were not only restricted to protecting the research participant but included the concepts of data reliability and validity, and the relativity of both truth and reality. The stated intension of the revision panel was neither to restrain nor to direct research but to offer a set of guiding principles.

These principles are laid out in point 6 (p. 5), which states that:

> … educational research should be conducted within an ethic of respect for:
>
> - The Person
> - Knowledge
> - Democratic Values
> - The Quality of Educational Research
> - Academic Freedom

Initially I had a problem with the concept of respect, as it can have different meanings for different people and it requires a moral framework in which to define the term. I found that there is greater acknowledgement of this dilemma

in the Australian Association for Research in Education's (*association for active educational researchers*) ethical code, which recognises the diversity of moral reasoning a researcher brings to the field. This code specifically identifies consequentiality, deontology and Aristotle's philosophy of virtue and deficiencies (*Code of Ethics* of the Australian Association for Research in Education (AARE)) as moral philosophies that could shape a researcher's view.

Research sponsorship: There are obvious potential problems with who owns the research and which way it will be guided. Can the researcher ever be free of the influence of the person or body holding the purse strings? The power relationship can impact both positively and negatively on the research process.

Research relationships: Again this is an issue of power within relationships, in this case the relationship between the participant and the researcher. How is the level of trust required for good research developed and used? What impact does the relationship have on the participant or how does this relationship affect the researcher? In practitioner-type research (action research) there can be problems regarding the role the researcher is taking: is he or she in the role of researcher or the role of teacher? This can lead to confusion on behalf of the participant and in some cases the researcher (Hollingsworth, 1991).

Informed consent is the central foundation of ethics in research. All researchers will give consideration to this issue if not all the other concerns raised here (Clark, 1995).

Data dissemination: How the data are used to shape either policy or practice is a potential issue to the researcher and the research community (Hill, 2001). How the results will be fed back to the participants, if at all, and how the data will be used by future researchers, along with problems of confidentiality, are all ethical concerns that need to be considered by the researcher.

Consideration of the ethical issues relating to my own research

Research sponsorship: As there was no sponsorship there were no restrictions placed on me from any outside agency. However, this did create other issues as the research still had to be completed to a time frame, not imposed by an agency stopping funding but by a necessity to return to work. Fundamentally this is the same issue as a lack of funds affecting whether there was sufficient time available to do justice to the investigation. In basic terms I succeeded in increasing my understanding of numeracy and have used this to effect change in my workplace. Financial support allowing more time would have enabled a greater understanding to be developed. This would have helped more practitioners to become involved and broadened the impact at my place of work.

Research relationships: Individual ethics and genuine concerns

I consider myself a moral person and having looked at the BERA code of practice I was less concerned with meeting the criteria of the ethics committee and more interested in alleviating my own ethical concerns. An ethics committee can stop blatantly immoral research from taking place but I doubt whether it can make us all moral agents. I can see how the need to satisfy an

ethics committee may force some researchers to consider whether what they plan to do is moral or not. How many researchers will bother to grapple with the underpinning philosophies of differing ethical stances is another question. Is it not more likely that they will do enough to pass the ethics committee's guidelines with no further consideration (Crotty, 1995)? My aim is not to allow myself to feel superior to other researchers but to underline my own feelings that there is always a moral and ethical responsibility when I deal with learners with learning difficulties and that this is even more important when I am undertaking educational research. My own ethical issues were: will my research injure or damage the learners in any way and can the learners give any meaningful informed consent?

Avoiding injuring and damaging the participant: Avoiding physical injury or harm to the participants did not appear to be a real concern even though the investigation took many incarnations. In my day-to-day teaching I have to be continually aware of risk, and assess the level of that risk to the learners in my class. This skill that I use on a daily minute-by-minute basis allowed me to be confident that this was a very low-level activity when it came to the risk of physical harm.

The level of risk of emotional, physiological or educational harm was less obvious to ascertain. Potentially the learners may be at risk of feeling different or picked upon or singled out for 'special treatment'. This was overcome by making the investigation an exciting and fun activity designed to be an activity that the learners wished to engage in. This was partially achieved by having the consent and support of the parents. Having achieved a desire on behalf of

the learners to be involved there was then another potential problem of supporting the learners after the ‘special time’ was over and whether they might feel rejected. I was fortunate in that the end of my investigation coincided with the end of the academic year and any loss of being involved with me and my investigation was lost in the overall transition to the summer vacation. However, this did create problems of feeding back the results to the parents and the learners, as contact was no longer weekly, necessitating feeding back in the new academic year. If I had had to deal with the feelings of loss at the end of the research I would have spent time after it was over preparing the learners for not having time with me once a week, by using techniques such as ‘what if’ scenarios and role play.

These potential feelings of loss do raise a broader question of how we prepare learners, in further education colleges, for the transition to new courses or even just to long periods away from the institution at the end of an academic year. The Estyn (2004) report, although looking at further education in Wales, highlights the lack of coherence in approaches to transition planning across the sector.

Problems with the dynamic nature of action research: consent left behind in the speed of change

My confidence in my ability to protect the health and well-being of the participants was misplaced, as highlighted by an incident with a diabetic participant. I had changed my method of research and to motivate the participants I had used chocolates as opposed to plastic bricks. One participant was diabetic; but for the timely intervention of another teacher I

would have given him a chocolate. As in the above case, as the action researcher adapts to the changes in situation and data the consent received at the beginning of the project may no longer be valid. By the nature of action research there is change in response to circumstances; the researcher cannot predict all these potential changes in directions the research may take and therefore cannot gain consent for what may happen. What has been consented to by the participants or their guardians at the beginning may no longer be valid.

The desire to change and chase every new idea may be a personality fault of only a few researchers or just me; however, the ethical dilemma highlighted by the diabetes incident is an issue for all action researchers. The incident raises the question of whether action research requires a different consent system to remain ethical? As the researcher changes and adapts the methods in response to the gathered data, as I did, have the participants consented to the change of circumstances; is the desire to do no harm enough to protect the participants? In most cases the answer will be yes as there will be no radical change in approach and the process will remain close to the original design, varying only in degree. How far must the process change from the original design before new consent is desirable or necessary and who should decide?

The Australian Association for Research in Education (AARE) code of ethics appears to address this issue most clearly as

> The information to be given prior to consent should include the nature and methods of the research, its purposes, any risks run by the

> participants, and the likely social and personal consequences of its publication and any other factors which might reasonably be expected to influence their willingness to participate**.** Participants should be informed of any changes in these considerations which occur in the course of the research. (AARE, 2006)

If I had continued to keep the participants' guardians informed of my change in methods the incident would have been avoided. However, constantly informing the participants of minor changes may well be impractical or necessary; also, if I had read thoroughly the notes available to me as a teacher then I would have avoided the mistake. It is imperative for the researcher to gain as much information to begin with as may be necessary to inform later decisions; this does however raise other questions of unnecessary intrusion and the participants' willingness to divulge what they consider personal or irrelevant information. There was an awareness of potential educational damage due to the learners missing classroom time and contact with their teacher. The teacher felt that short periods out of the classroom would not interfere with their education and she expressed some relief that the group size would be reduced and she could concentrate on those left in the class. This raised the concerned that the remaining learners would be gaining an advantage but reassurance was given that this was not the case as not all the research participants would be out of the class at the same time. They would therefore gain time due to the reduced staff–student ratio when another research participant was with me. It was discussed with the learners whether they would give up part of their break time so they did not miss so much of their lesson; all but one declined the offer. The issue of

avoiding educational damage was minimal due to the nature of the work undertaken in further education: there is no national curriculum to follow, and due to the honest relationship and trust I had with the teacher, I believe that she would not knowingly jeopardise the learning opportunity of the learners and if she felt that this was happening then she would not hesitate to tell me. This trust and openness between the teacher and me, as a researcher, was essential in allowing me to carry out the tests in an ethical way.

If educational damage was predicted as a possible outcome of the research I would have had two possible alternatives: to redesign the research method or to rectify any damage. How and what actions could place the learner back at a place where they would have been if they had not entered into the research would depend on each individual case and involve a certain amount of speculation: speculation on where the learner should be and what would be the best method to catch up. I was relieved not to be facing this particular dilemma.

Informed consent: I followed the BERA revised guidelines by writing to the parents to inform them of my interest and what I hoped to achieve, their right to withdraw their child and the child's right to withdraw. Although I received consent from the parents of my students to participate in my research I believe that consent is only the beginning of the ethical process. If we consider the level of understanding required for someone to give true informed consent we would end up only researching other educational researchers and then maybe only those knowledgeable in our style of research method. This becomes an absurd situation so there remains a

responsibility for the researcher to give such information to the participants that allows them an honest opportunity to assess the risks and desirability of taking part in any research.

Data dissemination: The main form of dissemination was through staff development sessions with other interested staff within the further education college. This was made easier on my return to work as I was given the role of chair of the numeracy committee for learning difficulties**.**

It was recognised that the parents needed to be informed of both the findings generally and any findings specific to their child. Through working with the students it was realised that two of the participants would understand to some extent the findings in their numeracy skills and could use the information for their own development.

The previous arguments and concerns over informed consent are still relevant and cannot be overcome merely by a more collaborative approach between the researcher and the participant. Whether the research is ethical or not is still primarily the responsibility of the researcher and cannot be mitigated by participants being involved in the design.

The participants' true power in shaping the design is questionable as they will not have the skills or knowledge to contribute fully; in many cases the participants will be children of school age or learners with cognitive impairment. However, action research's stress on collaboration and participation is a step towards greater egalitarianism. The change in the term

from subject to participant alone shows, if not a genuine shift, a subtle move in the power relationship.

It represents a shift from those carrying out the research and those having research ‘done on them’, to a relationship of the researcher and those involved in the research. Malvicini (2000: p. 1) poses the question ‘Who really benefits from research questions in … education?’ His answer is ‘does not the person asking the question benefit the most …?’

Although demonstrating his particular view of the world of academic research, it demonstrates a real potential strength of action research. If the research ‘participants’ or educational community is involved in the shaping of the research question and the parameters of the research to be undertaken they will receive a greater benefit. It becomes their research and is better than having ‘research done on them’ by a researcher.

Chapter 3

THE INITIAL DATUM TEST

This chapter describes the data-collecting tools that were used initially to test the participants' baseline numeracy skills. There is a description of the tests, what they were intended to measure and how potential issues with observation were recognised and taken into account.

Developing the datum

It was essential before the intervention could take place to develop a datum to measure effectively any improvements the interventions may bring. Initially it was considered that to investigate numeracy development successfully a reliable quantitative test to measure the learners' counting skills would be sufficient. A re-test at the end of the intervention would assess whether there had been any improvement and if the intervention had been effective. The greater objectivity of a quantitative over a qualitative test made the quantitative type of test more attractive. The subjectivity implicit in qualitative tests could potentially invalidate any findings and open the results to criticism. McConkey and McEvoy's (1986b) tests appeared to deliver a high level of objectivity. As counting is often the first number skill taught (Lave, 1988; Rogoff, 1990) this seemed a logical place to start. When designing the datum test it was important to ensure that it measured each participant's counting

skills. It became apparent that these tests were too advanced for these participants.

Using a test from McConkey and McEvoy

It was clear that one test could not cover all the aspects and components of counting. As stated, McConkey and McEvoy had developed a set of tests that appeared appropriate for the task. They developed these while working for the Association of Parents and Friends of Mentally Handicapped Children, entitled *Count Me In* (1986) and published as ‘Games for learning to count’ (1986).

Their four tests are counting, numerals, ‘how many’ and ‘give me’.

The tests

Counting: Counting was subdivided into four tests. Learners were asked, “Can you count as high as you can?”, which allowed them to demonstrate whether or not they had mastered the stable order principle.

In test two, the learner was told, “I am going to say three numbers. See if you can continue on from where I stop”. This checked a level mastery of the stable order and indicates the breakable-chain level of development (Fuson et al, 1982). If the participant was unsuccessful in this test and always had to start at one this could indicate that the number sequence has not been mastered and is just a string of words (Fuson et al, 1982). There could be no concept of this being a string of numbers and it had no more meaning than a nonsense poem.

Test three was similar; the participants were asked, “Can you count backwards?” This would demonstrate a bi-directional string level of development (Fuson et al, 1982). The fourth test was optional: “Can you count in tens?”

Numerals: The participants were tested in their ability to recognise the Arabic numerals 1 to 12 by being shown cards and the result of their verbal response recorded. This ascertained whether the participants could read the numbers.

How many: A set of objects was gathered together in advance and the learner was asked to say how many there were of the given number of the objects as the set size was changed. This tested one-to-one correspondence (Gelman & Meck, 1986) and was a check on whether the participant understood cardinality.

Give me: This test was a more advanced check on the understanding cardinality as the participant could not rely on pointing alone (Fuson & Hall, 1982). From a large set of objects the learner was asked to give a smaller subset. This tested whether the learner stopped on the requested number.

Problems with administrating the tests

These tests had been designed to take into account that these participants had learning difficulties and poor literacy skills; these participants would have found it impossible to take a written test. Therefore, someone had to administer the test and the researcher was required to be more involved than would have been the case with more able learners, who could read and write sufficiently to perform a written test themselves (Porter & Lacey, 2005).

The test was a highly structured observation (Cohen et al, 2007) and as such consideration had to be given to the potential problems and effects of the act of observation.

Consideration had to be given to how the act of observing could impact on the results: could these impacts be eliminated or reduced and if this proved impossible could they be accounted for?

Potential observation effects

In the field of educational research there are four potential effects recognised in the act of observation that can affect the data, which are: observer bias, the Hawthorne effect, the observer-expectancy effect and the participant-expectancy effect.

In 1980 Salvia and Meisel analysed the published research from the previous 2 years that had appeared in 4 journals in the field of special education. They criticised the research claiming that 48% was potentially flawed and had a high probability of observer bias, as the researchers had taken no precautions to safeguard the validity of their observations.

With this in mind it was important to be aware of the four potential effects recognised in the act of observation that can affect the data.

Observer bias

Observer bias occurs when the observer overemphasises the observed behaviour to fit a preconceived notion of what should happen, or fails to notice

other significant behaviour they did not expect (Rosenthal, 1969). This is not necessarily a conscious decision.

Observer expectancy

Similar to observer bias, but subtly different, is the observer-expectancy effect. This is caused when the observer expects certain results and sub-consciously manipulates the experiment, or misinterprets the data, to fit the premise (Rosenthal, 1966).

The Hawthorn effect

The Hawthorne effect is where the participant being observed changes his or her behaviour due to the act of being observed (Pugh et al, 1971).

Participant expectation

Participant expectation happens when the participant has a preconceived idea of what is expected from the experiment, and manipulates the experiment or reports results in line with his or her expectation. This is of greater concern in medical testing and has led to double-blind testing and the use of placebos to negate these effects (Kaptchuk, 2001).

How to eliminate or reduce the observer-induced errors

Recognising the potential effects is one thing; eliminating or reducing their affect is another. Salvia and Meisel (1980) suggest a simple method of reducing systematic errors in observation by keeping the observer unaware of the purpose of the experiment, and of as many irrelevant participant

characteristics as is possible. This was obviously impossible in this research and in many forms of action research and only works where raw data are required. Subtle nuances or important data can be missed if the observer does not see the relevance.

More practically Kazdin (1977) investigated observer bias and how to reduce the effects. He identified four main potential issues:

- **Reactivity of reliability assessment**: observers improve when they know the accuracy of their observations is being checked
- **Observer drift**: observers tend to 'drift' away from the original criteria; inter-observer agreement may not indicate a lack of drift, especially with observers who maintain close contact
- **Complexity of the observational coding system and behaviour scored**: the more complex the categorisation the less consistently and accurately it will be applied
- **Observer expectancies and feedback**: the effect of the observer's expectation of the behaviour of the participant and the effect of the feedback by the observer on the participant about that behaviour

Applying Kazdin

Using Kazdin's conclusions, consideration was given to the possible impact on this research and how to deal with these issues.

Reactivity of reliability assessment: Another researcher could observe the researcher, in the role of observer, using the data collection tool, having agreed on a clear protocol. Alternatively the researcher himself could have

observed another observer using the data tool, having received sufficient training. This seemed a possible solution as better results are also generated when the observer believes that the reliability of the results will be checked against another observer (Romanczyk et al, 1973). Congruence in itself does not mean validity (Landis & Koch, 1977; Rosenthal, 1969). Another observer may agree with the results but may only be reproducing the same bias and errors as other observers either through training or through culture.

Observer drift: Using another person to administer the tests would require a clear protocol to create a level of consistency. Training can reduce the level of bias (Madle et al, 1980). There would be an expectation that the test administrator would follow the protocol. There is an example that this does not always happen in the McConkey and McEvoy (1986a) video, which was designed to enable parents, guardians, friends and carers to access the tests and activities to develop number skills. An observer fails to follow the protocol and erroneously administers one of the tests. In this case a learner had already demonstrated that they could not successfully count beyond eight but the test administrator when testing the ability to 'count backwards' used the sequence fourteen, thirteen, twelve: well outside the learner's success range. Failure was guaranteed; even after adjusting to twelve, eleven and ten the numbers were still outside the learner's range of competence. Here was an example of someone not fully aware of what they were testing and making an error that the developer of the test would quite reasonably expect not to happen. However, a willing observer who was available when the participants were available could not be found.

Complexity of the observational coding system and behaviour scored: The data collection tool was simple; for each test there was either an integer answer or an achieved/unachieved result. When the tests were conducted this was found not to be as simple as first believed.

Observer expectancies and feedback: This was the most problematic as there were very clear expectations and the importance of the potential impact was recognised as well as the need to be mindful of this when carrying out the tests. However, being aware of your potential bias does not in itself reduce the bias (Bloom & Tesser, 1971: in Salvia & Meisel, 1980).

Gathering the data

Armed with these tests it was necessary to find suitable participants who were willing to take part in the research. Through discussion with colleagues several potential learners were identified to work with. They were a group of young male adults with severe learning difficulties that attended college three days a week. Early in the academic year the data collection tools developed from McConkey and McEvoy (1986) were administered to gather the data.

Chapter 4

Investigating number skills

In this chapter there is a description of how the McConkey and McEvoy tests were used to ascertain the level of numeracy ability of the four participants. There is also a description of how the results and the way the participants acted in the tests revealed the limitations of the tests and how there was a radical need to modify the method of administration. The realisation that much information was likely to be missed if the tests were administered in such a restrictive manner again challenged the prejudices of the researcher and encouraged a reassessment of attitude as well as methodology.

The plan

Four learners were selected from a group of young males with severe to moderate learning difficulties. Several factors influenced this decision, including the co-operation offered by the teaching staff, who were very amenable and allowed time out from class so the participants could access the sessions. The limitation of the time available was also a factor, both the amount of time available each week to the participants and the number of weeks left to the end of the academic year. The four participants demonstrated a range of ability allowing and even necessitating the use of individualised interventions. The initial interest of the project was less in

general teaching methods and more in the need for personalised learning strategies to meet each learner's individual needs.

Initial baseline testing

The first set of tests highlighted the messy nature of real-life social science research (Cohen et al, 2007) with real people and that as it was impossible to follow the strict protocol that had been set, a level of flexibility was required. This flexibility was found to be a useful, practical solution to the problem and underlined the strength of the action research method and its appropriateness for this research project. Analysing the data generated from the baseline tests seemed to indicate that the tests were not sensitive enough to measure the skill level of the participants. This guided the research into an area where there was greater concern for the broader implications of the findings than just the baseline abilities that were being measured. The realisation that the tests were too advanced and consequently the recognition for the need to modify and adapt was an example of how valuable the action research cycle can be. The consequence was to adopt an approach that allowed for a more immediate response to what was happening during the tests.

Analysis of the results taken on 9th January 2006 and 27th May 2006

The initial plan was to test on the 9th January 2006 and to allow the participants to follow their normal college routine then to test again in May 2006. This would give some indication of the development of numeracy skills that the participants gained from their lessons at college. This development could then be taken into account and adjustments made for the success of

any improvements from the project's interventions and thus improve the validity of the results and findings.

The first tests were carried out during an afternoon domestic skills lesson. The participants were taken out of class individually and the researcher administered the tests.

Initially the intention was to analyse the data in a quantitative manner, to aid objectivity; it soon became apparent that this was only giving part of the story. Many interesting and major factors would be ignored if this technique was pursued.

Counting aloud

Gary T

a) "Count as high as you can"

Date	9/1/06	27/5/06
Highest* number	6 (13) He said 11 instead of 7 but can clearly count well	10 (29) He pronounced 7 as seven but 11 as eleventeen. 30 became twenty-eleven

*Highest number recorded without any mistakes or prompts.

In this test each participant was asked to count as high as he could.

Student Gary T counted to six without error; this was his quantitative datum. However, his error was to pronounce seven as “eleven” and if this mispronunciation mistake was ignored he counted successfully to thirteen.

This was the first issue with the collection of data and the method in use.

The initial intention had been an objective scientific test and therefore Gary’s inability to say seven correctly created a dilemma. Gary T could count successfully beyond six but his pronunciation was letting him down. The objective test results for Gary indicated that he had only counted to six without error. A problem had occurred with the data collection method; if applied stringently it could not collect the full, rich data being generated and could not fully reflect Gary’s ability with numbers. The test had become a test of Gary’s pronunciation of the number words and no longer a test of his ability to count. Yet dismissing Gary’s mispronunciation and ignoring his inability to enunciate the word seven clearly is also to ignore the implications for Gary in his everyday life. If Gary needs to indicate the number seven he will say eleven, due to his pronunciation problem, and will always be four out. When Gary is counting the mistake will probably be noticed as an error in pronunciation; however, when this error is made on its own the mispronunciation error, to someone who does not know Gary, will appear as an ordinal or cardinal mistake. The implications for Gary could be immense; he will ‘fail’ any query made of him where the answer is seven. For example if asked, “when do you get up to get to college?”, if the answer was seven o’clock he would actually say “eleven o’clock”: patently wrong as he is in college for a nine o’clock start.

The apparent trivial nature of these problems masks the potential adverse impact on the way Gary interacts with others. How people judge Gary's abilities to act independently is potentially enormous.

Nowhere in Gary's records was there any mention of this problem; the information was passed on to his personal and numeracy tutors. In a later session it was explained to Gary the problem people had with mishearing what he was saying, and he made a great effort from then on to say seven and not eleven when working with the researcher. This was reflected in his success in the next test when saying the word seven.

The rule of teens

Gary also confused the rule for eleven and the teens; Conway's (1995) explanation would indicate that Gary is making a reasonable mistake for someone whose number skills are not yet stable. This also supports the contention that the teens take longer to learn (Baroody, 1992). It was also possible that Gary was still at an early developmental stage of numbers and had not shown any progress from a very early age (Benson & Baroody, 2002).

Reflection

Observer expectation had been demonstrated on the very first attempt at data collection in that notes were made on the side of the checklist to indicate any anomalies. This demonstrated the difference between observer bias and observer expectation; there was clearly no indication of observer bias as other data that had not been anticipated were not ignored but recorded. It was concluded that this data-collection method for establishing quantitative data

and analysis was in fact throwing up unclear results for this group of participants. More interesting and relevant results were available only by ignoring the protocol. It was necessary to adopt a qualitative approach and record more information and the observer's views while collecting and analysing the data. This would allow the gathering of datum but also look outside the narrow framework.

The following analysis reflected both the quantitative and qualitative nature of the data collection and the flexible attitude adopted towards the data and the methods of collection.

Analysis of the initial test

Using the counting test merely as a datum indicated that Gary T could count to six. However, considering the data gathered outside the protocol showed that Gary T can count confidently to thirteen. The second test demonstrated that Gary T had not fully mastered the stable order principle as he was demonstrating the first phase of a stable conventional section followed by a non-conventional stable sequence (Fuson et al, 1982).

Counting on

b) "I'm going to say three numbers; see if you can count on from where I stop?"

Date	9/1/06	27/5/06
Highest* number	19 I started with 6, 7, 8 He said 21 instead of 20	14 I started with 6, 7, 8 He just stopped at 14

*Highest number recorded without any mistakes or prompts.

The counting started with "six, seven, eight". Gary T counted on to "nineteen", he counted twenty as "twenty-one" then repeated "twenty-one" and he then stopped. This possibly demonstrated that he recognised an error. The datum indicate that he can count on to nineteen compared with only thirteen on the counting from one test, raising the question of whether the starting digit has an effect on his ability. This could be a matter of concentration. Again this test confirmed that he was still demonstrating the non-conventional stable sequence in his counting (Fuson et al, 1982).

His ability to 'count on' indicated that he had advanced beyond the first level of learning the counting words as a single string and is at the breakable-chain level. At the single-string level the string starts at one (Fuson et al, 1982); at the breakable level it can start at any number.

Interestingly, when he counted to both thirteen and twenty-one he counted thirteen times in each case. At the time Gary counting thirteen times was not

noticed; the later tests did show that Gary could count for more than thirteen digits, which indicated that this observation was, although interesting, just a random occurrence.

The sequence started with six, seven and eight to remove seven from the sequence to enable a better chance for Gary to demonstrate his counting skills rather than his pronunciation deficiencies.

Counting backwards

c) "Can you count backwards?"

Date	9/1/06	27/5/06
Lowest* number	None	None

*Lowest number recorded without any mistakes or prompts.

Gary T could not count backwards. This would indicate that he has no understanding that the number line can go backwards as well as forwards and has not yet understood the bi-directional nature of the chain (Fuson et al, 1982).

Gary T may have an understanding of the number sequence similar to most people's understanding of the alphabet. Many people are comfortable moving forwards through the alphabet sequence but struggle when asked to recite the sequence backwards from any given three letters or if asked what letter precedes any given letter. The number sequence is easier to deal with as we have an understanding of that extra element that each number has associated

with it, a quantity that places the number in a unique place in the order. The integer n will be one greater than n-1 and one less than n+1 (Butterworth, 2000), giving n a unique place in the sequence. Any n's place can be identified from that of any other n if the rules that govern integers are understood; this is an initial step towards simple addition and subtraction. Not being able to count backwards, as in this case, implies that the number sequence is not fully stable or that the concept of ordinality has not been grasped, supporting the contention that counting in itself tells us very little (Geary, 1994).

Counting in tens

d) "Can you count in tens?" "10, 20, 30 …"

Date	9/1/06	27/5/06
Highest* decade	90 I started with 10, 20, 30, 40 He said 20 after 90	50 I started with 10, 20, 30 He stopped at 50

*Highest decade recorded without any mistakes or prompts.

Gary T needed some encouragement but finally succeeded in counting in tens to "ninety". Consideration of the results led to questions over the value of this particular test. The results may only show that the student has learnt another sequence verbatim rather than a concept of the decimal system. It is improbable that this sequence has number relevance to him and is not a useful step to gaining numeracy skills, unlike the practice afforded in Old Chinese (Aunio et al, 2004).

Mark

(a) “Count as high as you can”

Date	9/1/06	27/4/06
Highest* number	14	15

*Highest number recorded without any mistakes or prompts.

On both occasions that Mark took the tests he did well as he reached 14 and 15 without any errors. This demonstrated that he had learnt the number words in sequence and was at least at the single-string level (Fuson et al, 1982).

“Count on”

b) “I’m going to say three numbers; see if you can count on from where I stop.”

Date	9/1/06	27/4/06
Highest* number	4	None

*Highest number recorded without any mistakes or prompts.

Mark managed to continue to four possibly ‘joining in’ with the number names; however, on the second test he made no response. Mark has clearly demonstrated his level of ability; he only knows the numbers as a single string. It would have been interesting to investigate whether he had a

comprehension of the numbers existing as individual numbers, the unbreakable list stage (Fuson et al, 1982).

"Counting backwards"

c) "Can you count backwards?"

Date	9/1/06	27/4/06
Lowest* number	None	None

*Lowest number recorded without any mistakes or prompts.

Mark demonstrated no ability to count backwards, again indicating that he only knew the counting words as a string. He was possibly still at the stage where reciting the counting words was an act in itself (Fluck & Henderson, 1996).

Mark's experience of this test may be similar to the alphabet test mentioned previously, that if given three letters in reverse order and asked to continue the sequence most people struggle. This task of continuing the alphabet backwards was used to demonstrate the problem of learning number sequences during a workshop for practitioners who were working with people with learning difficulties. Not only did the practitioners struggle to perform the task of reciting the alphabet backwards but it was found to be difficult to write clear instructions so that others could administer the task. The plan was that the practitioners would work in pairs and testing each other's ability to write unambiguous instructions took several drafts and dry runs. This experience during the workshop could indicate that we have set expectations and when

we move away from these we are often confused. This may be what happened to Mark, where the request to count backwards is so absurd that it becomes impossible. The test results are still an indication of Mark's lack of understanding of the bi-directional chain (Fuson et al, 1982).

"Counting in tens"

d) "Can you count in tens?" "10, 20, 30 …"

Date	9/1/06	27/4/06
Highest* decade	None	None

Mark could not do this.

In summary Mark had limited number skills. He was probably functioning at a stage of string level or at best unbreakable-list level (Fuson et al, 1982).

David

David's lack of language skills placed extreme challenges on administering these tests. David's lack of speaking skills was not sufficiently taken into account before the tests. Discussions with staff who regularly support David indicated that he demonstrated many challenging types of behaviour. It was decided to try and use these number sessions to engage with David; although he had not completed any task, he had engaged in the process and demonstrated no challenging behaviour.

a) “Count as high as you can”

Date	10/1/06	27/4/06
Highest* number	Repeated “a”	Repeated “2”

*Highest number recorded without any mistakes or prompts.

b) “I’m going to say three numbers; see if you can count on from where I stop.”

Date	10/1/06	27/4/06
Highest* number	No response	No response

*Highest number recorded without any mistakes or prompts.

c) “Can you count backwards?”

Date	10/1/06	27/4/06
Lowest* number	No response	No response

*Lowest number recorded without any mistakes or prompts.

d) “Can you count in tens?” “10, 20, 30 …”

Date	10/1/06	27/4/06
Highest* decade	None	None

David could not access these tests as they were too reliant on his language skills. It was necessary to find a way for him to demonstrate his skills in ways that did not require him to say the number words.

Gary A

a) “Count as high as you can”

Date	10/1/06	27/4/06
Highest* number	33 >**	20*** 31 (without noise distraction)

*Highest number recorded without any mistakes or prompts.

** The learner was asked to stop, as he was very competent.

*** Loud heavy metal music from the next room distracted Gary. When we moved to a quieter room he scored 31: not as good as on 10 January.

Gary had excellent counting skills; on the first test it was necessary for the observer to stop him as he clearly was a long way off his limit and this level of skill had not been expected. On the second occasion he was distracted, as was the observer, due to very loud music coming from the classroom next to the one where the test was taking place. However, when moved to a quieter environment he could only count to 31. It was felt that he was still distracted and lacked motivation for the task. There had been little anticipation and preparation for the potential impact of these types of problems. This did act as a demonstration of the messy nature of researching in a real teaching environment.

“Count on”

b) “I’m going to say three numbers; see if you can count on from where I stop.”

Date	10/1/06	27/4/06
Highest* number	37>	19 25 (without noise distraction)**

*Highest number recorded without any mistakes or prompts.

** Counted up to 25 then 36, 37, 38; distracted then moved up a decade.

Gary had no problem with this task on the first occasion. Again the noise from the other room distracted him and it could be argued that there was still a residual effect when moved to another room away from the noise. Stopping the test and commencing on another occasion may have worked better. The distraction did expose a problem with the consistency with which Gary performed as a counter. Having counted to 25 Gary then counted 36, 37 and 38, indicating that he did not fully understand the number order and that the sequence was not as stable as first thought. The noise from the other room had demonstrated that Gary could relapse to the non-conventional stable sequence whose existence had been questioned (Wagner & Walters, 1982: Baroody & Price, 1983). It would be difficult to make this error if he had full understanding of the number sequence and the anomalies and rules of the English system (Baroody, 1992).

“Counting backwards”

(c) “Can you count backwards?”

Date	10/1/06	27/4/06
Lowest* number	12	11

*Lowest number recorded without any mistakes or prompts.

Gary had demonstrated that he was functioning at the level of the bi-direction chain and that he had learnt the number sequence well, yet the previous test had shown this to be less advanced than these results would indicate. This raises a question on the nature of these counting tests and whether Gelman and Meck (1986) were giving too much emphasis to the mechanism of counting when demonstrating a stable order. With a good understanding of the developmental stages of learning to count this can be a useful tool but it could also give rise to an inflated expectation of numeracy skills. At face value Gary has demonstrated his ability to count, yet he is repeating a word sequence. To master the skill of counting truly, he must achieve many more steps and that is before he can use the skill to develop more advanced mathematical skills.

These initial tests had shown that even the stable order principle was complex and often inadequately tested, and that some learners could learn the counting words before having any understanding of counting (Briars & Siegler, 1984; Frye et al 1989; Wynn, 1990; Caycho et al, 1991; Fluck & Henderson, 1996).

Counting in tens

(d) “Can you count in tens?” “10, 20, 30 …”

Date	10/1/06	27/4/06
Highest* decade	90**	***

*Highest decade recorded without any mistakes or prompts.

** Counted competently to 90 then said 20.

*** Only counted 14, 15, 16.

The results for Gary were confusing as he counted very well on the first occasion yet due to external factors could not comprehend or access the test on the second occasion. This indicates that concentration and engagement are important to Gary. This will have an impact on later tasks and how he engages in number work in his everyday life.

Testing how many

Gary T

Number of objects recognised

Date	9/1/06	27/4/06
1	✓	✓
2	✓	✓
3	✓	✓
4	✓	✓
5	X 6	✓
6	X 7	X 8
7	✓	X 9
8	✓	✓
9	✓	✓
10	✓	X 17
11	✓	X 10
12	✓	X 14

27th May 2006: He always has to count when groups have more than two objects (can recognise one, two). Errors occur when the balls are too close together or too far apart, leading to confusion.

The results indicate that Gary T was successful at identifying groups of tennis balls one through four and seven through twelve with errors in identifying five and six. Using this type of data as a datum presents some problems; it would seem reasonable to assume the integer four as the datum as this was the largest integer that the student identified before there was an error. However, as the test was not given in numerical order four was not the last successfully

identified set of balls, which was in fact nine. Other factors need to be considered, such as the level of concentration and interest. It was realised that it was necessary to take greater account of the test conditions and how preparation for the tests is of great importance in ensuring that all the variables and the sequence of events are recorded accurately. From a research point of view, although the ability to respond to situations is important, preparation to respond and also minimising the necessity of variations helps immensely.

The notes did indicate that Gary was demonstrating the early stages of development and using the two skills of using the counting words in order and keeping track of the objects being counted (Alibali & DiRusso, 1999). Gary was using his competence with a stable order to ten reasonably well, yet he was still making mistakes demonstrating many of the problems identified by Fuson et al (1982). When the balls were too close together or too far apart his problems could be related to the need to use his visuospatial ability more than just language (Sarama & Clements, 2009). There is a need to repeat this test and pay greater attention to the mechanics of counting that Gary uses. Subsequent reading exposed the developmental stages of one-to-one correspondence but at the time the observer was not in possession of this knowledge and therefore did not recognise the need for recording the mechanics used in the counting of objects.

Mark

Number of objects recognised

Date	9/1/06	27/4/06
1	✓	✓
2	✓	✓
3	✓	X (4)
4	✓	X (2)
5	X (6)	X (1)
6	✓	X (3)
7	X (9)	X (2)
8	X (9)	
9	X (20)	X (4)
10		
11		
12		

On 9th January Mark was successful up to four but only up to two on 27th April. The number of actual balls given on request indicates that Mark does not fully understand the amounts one or two or three; if he did then he would not give these amounts when five, six and seven were requested as he would know this was incorrect. Where it would appear from the original results that he was one-to-one up to three the later results show otherwise. This emphasises the need for repeat testing; drawing conclusions from the first set of results could have been erroneous. The second test does not show that Mark does not understand the concept of one or two or three, but there is a strong argument that he does not when combined with his stable order

results. There is a need to test Mark or observe Mark in his normal everyday life (Wilson, 1977) to assess his understanding of quantity.

David

Number of objects recognised

Date	10/1/06	27/4/06
1	X	X
2	X	X
3	X	X
4	X	X
5	X	X
6	X	X
7	X	X
8	X	X
9	X	X
10	X	X
11	X	X
12	X	X

David demonstrated no understanding of amount; clearly there is a need for a more ethnographic approach to see how David functions in his own environment (Wilson, 1977). What could David do in his own world that would demonstrate a concept of amount? Does he always put the same number of spoons of sugar into tea; does he match the number of plates to knives and forks; can he match cups and saucers? All these would be better tests of David's number skills.

Prior to the testing David had been observed with all the participants in a numeracy lesson to see what sort of learning they were experiencing in these teaching sessions. It was observed that a teaching assistant rewarded David for saying the word two when given two objects or shown the Arabic

representation of the number two. There was no varying of the numbers or objects in the early stages of the session and so David learned that when he said “two” he was rewarded with praise. The positive reinforcement only reinforced David’s repeating of the word “two” and not the association of the number or the objects with the word. This was evident later when the number and the number of objects were increased; from later work it also had an adverse impact on his interaction with all numbers.

Gary A

Number of objects recognised

Date	10/1/06	27/4/06
1	✓	✓
2	✓	✓
3	✓	✓
4	✓	✓
5	X (4)*	✓
6	✓	X (7)
7	✓	✓
8	X (7)*	X (9)
9	X (7)	✓
10	✓	✓
11	✓	X (12)**
12	✓	X (11)***

*He missed the first object on these counts (common error; Fuson et al, 1982).

**Counted one object twice.

***Used touching strategy but could not remember which number came after 9 (another common mistake; Fuson et al, 1982).

Gary A had clearly demonstrated the best number skills of all the participants. His understanding of stable order and one-to-one correspondence was reasonably sound. He had the most effective strategy for dealing with counting as for bigger sets he used a touch strategy (Fuson et al, 1982).

This was not a fail-safe strategy as on two occasions he missed the first object and once counted an object twice, common errors in the later stages of developing this skill (Fuson et al, 1982).

A better strategy for Gary A would be moving the object after it has been counted. This only works for small objects but reduces the need for memory (Fuson et al, 1982).

The limits of the working memory were identified in 1956 by Miller. His work suggested that we all need strategies to help our working memory; Miller suggested the concept of chunking.

“Can you give me?” (Cardinality, one-to-one correspondence)

Gary T

Recognised

Date	9/1/06	27/4/06
1		
2		
3		
4		
5		✓
6	✓	
7		
8	✓	
9	✓	
10	✓	
11	X 7 X 12*	X 7 X 7**
12	X 10	✓

* He stopped when he counted to 7 as he pronounced it 11; on his second attempt he ignored the mistake and continued until 12.

** He stopped at 7 as he pronounced 7 as 11; on the second attempt he made the same error.

The ‘give me’ test was again inconclusive; Gary T was successful on some occasions but failed on others, raising the same questions as for Gary A. An interesting incident occurred when he was asked, “can you give me eleven?” The student stopped at seven as he mispronounced the seven as eleven.

Assuming he has fuzzy language and uses a word that sounds enough like the correct word to him it is possible to assume that Gary T has good cardinality skills (Gelman & Meck, 1986). He counts the objects and stops when the requested integer is reached yet demonstrates little understanding of ordinality (Sarama & Clements, 2009). On the second attempt he just ignored the pronunciation error and worked his way through to the proper eleven, showing good understanding of ordinality.

Mark

Recognised

Date	10/1/06	27/4/06
1	2	10
2	4	**
3	3*	**
4	3	
5	3	**
6	3	
7		**
8		
9		
10		
11		
12		

* Called it 4.

** Just carried on counting out.

Mark did not appear to comprehend the task. All his first test results on 10th January were low numbers up to four objects and on the second occasion on 27th April he carried on counting, a common error in the early stages of development (Fuson et al, 1982). On the second occasion Mark demonstrated better stable order skills than in the counting test, which would support

Paterson's (2001) assertion that children, or in this case adults, concentrate more on the novel than the ordinary.

David

Recognised

Date	10/1/06	27/4/06
1	X	X
2	X	X
3	X	X
4	X	X
5	X	X
6	X	X
7	X	X
8	X	X
9	X	X
10	X	X
11	X	X
12	X	X

David did not give any balls but was content to pick them out of the bucket and put them back. There was no pattern.

Gary A

Recognised

Date	10/1/06	27/4/06
1	X (2)	✓
2	✓*	✓
3	X (2)	✓
4	X (2)	✓
5	X (2)	✓
6	X (2)	✓
7	X (2)	✓
8	X (2)	X (8+7)**
9	X (2)	✓
10	X (9)	✓
11	X (6)	✓
12	Gave all (24)	X (11)

*Initial success with the number 2 then looking around distracted, unable to refocus.

**He had not returned the previous balls so gave me eight counted out plus seven from the previous “give me”.

On the first test date Gary A was disengaged by the time this part of the test took place, which impacted on his performance. On the second test date he did much better and was more successful than he was with the ‘how many’ test. This supports the proposition that a better technique for him is to give or move objects away (Fuson et al, 1982). It also shows that he has good ability in comprehending the cardinal principle.

Arabic numerals assessment

Gary T

Arabic numerals recognised

Date	9/1/06	27/4/06
1	✓	✓
2	✓	✓
3	✓	✓
4	✓	✓
5	✓	✓
6	✓	
7	Mispronounced as 11	Mispronounced as 11
8	✓	✓
9	✓	✓
10	✓	✓
11	✓	✓
12	21*	✓

* Transposed digits 2 and 1; when prompted he corrected himself.

Gary T was very successful at recognising Arabic numerals but again mispronounced 7 as “11” and transposed the digits of 12 and called it “21”. As with the ‘how high can you count’ test this test does not test whether the student has any ordinality comprehension nor whether he can attribute this to the Arabic numeral. A more relevant test would have required the learner to demonstrate whether he could place the numbers in order. This would test the assumption that if he could order them verbally he would be able to transfer

this skill by matching the oral word to the numeral and then order as before, an assumption that requires testing.

Mark

Arabic numerals recognised

Date	10/1/06	27/4/06
1	✓	✓
2	✓	✓
3	✓	X (4)
4	✓	X (2)
5	X (6)*	X (1)
6	✓	
7	X (9)	
8	X (9)	
9	X (20)	
10		
11		
12		

* Possibly tired.

Mark demonstrated that he had some number recognition skills, but they were not stable. The test was stopped on 27th April as he was having little success.

David

Arabic numerals recognised

Date	10/1/06	27/4/06
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

No numbers were recognised in either test. David was playful and charming, and tried to engage me in his interpretation playing with balls and stacking objects, but showed no number skill.

Gary A

Arabic numerals recognised

Date	9/1/06	27/4/06
1	✓	✓
2	✓	✓
3	✓	✓
4	✓	✓
5	✓	✓
6	✓	✓
7	✓	✓
8	✓	✓
9	✓	✓
10	✓	✓
11	✓	✓
12	✓	✓

Gary proved conclusively that he could name the Arabic numbers but the test did not establish whether or not he could associate ordinality or cardinality with the numbers.

Action research cycle

Each time a student was tested more questions were generated than answers; it was necessary to pick apart the initial assumptions in order to find more appropriate ways of testing the learner's skills and understanding. For example, to test the students' understanding of quantity they had to say how many tennis balls there were in a group. This at face value tested an understanding of cardinality; it relies on one-to-one correspondence, the

stable order principle and the cardinal principle (Gelman & Meck, 1986); however, it does not demonstrate any understanding of ordinality. That is, you can stop at four items when there are four items and stop at five when there are five, without knowing that four is less than five. The need for a different test was apparent, demonstrating the usefulness of the action research cycle proposed by Elliott (1982), whereby action and reflections are followed by amended actions. As the only access to the students was once a week for a few weeks there were clear advantages to the use of this approach. The immediacy of the reaction to the reflections based on the findings from each session was a strong point.

Adaptation

The lack of success of the baseline tests created the need for re-emphasis and a new direction. Without the baseline there is nothing to measure the success or otherwise of any intervention and the initial research question could not be answered. In response to this a reliable test of number awareness was sought, yet a greater prior knowledge of the available research, such as the work of Fuson et al (1982) or Paterson (2001), would have led in a different direction. This topic of investigation remained of interest, as it offered some insight into discovering whether there was a need to teach learners numeracy in sessions based on an understanding of cardinality and ordinality.

The tests

It became apparent that the successful completion of some of the tests did not actually mean mastery of the number skills that it was initially believed were being tested. Mark could count to four on one occasion but not on another; Gary T failed prematurely due to problems with his pronunciation; Gary A's success was determined by his level of concentration. This not only highlighted problems with the tests themselves but in the way they were administered and the way the data were recorded. It was necessary to record more than just the quantitative data to help contextualize any data.

A truly ethnographic approach would require observation of the participants in a natural setting (Wilson, 1977) and gathering of naturally occurring data; the problem for this study was that the students do not tend to encounter counting in naturalistic settings. This is quite an indictment of the course they are attending and the attitude towards the students' relationship with number by those dealing with the students in all aspects of their lives. By removing the student from the class an artificial situation was created. In Gary T's case, the results led to other questions on the nature of counting and how knowing the number sequences is only part of the skill of counting (Fuson et al, 1982).

It was decided to investigate how we develop the ability to count invisible or non-concrete objects. It was felt that counting these would demonstrate a level of counting skill that would show how well the participants could really count, not relying on the objects as a prompt or reminder of what had been counted before. Although it was realised that this was a more difficult task it was not appreciated that the participants were functioning at a higher

developmental level. At this time the work of Fuson et al (1982) had not been read; if their work had been read then tests to access the skills of the stages of counting-string development would have been deemed more appropriate.

Chapter 5

SEARCHING FOR THE LEVEL OF ABILITY

In this chapter the attempts to understand the participants' true numeracy skills are described, and how, in response to the initial test results, techniques including drumming were used in an attempt to explore other aspects of numeracy. The interactions are described in some detail to show how the exchanges between the researcher and the participants drove the changes in the testing regime. The detail also highlights the constant reflection that was taking place and how the research changed in response to the results of the tests generated by the participants. What the results demonstrate about the participants is discussed in light of later reading of the literature available on these basic numeracy skills.

Deliberation has been given to how best to describe the research process: whether to write about each session in chronological order or to follow the theme of each individual learner. The first choice was to write in chronological order, as this reflected more accurately what happened on each visit to the college and the thoughts generated during each visit. However, this proved to create a disjointed narrative that was difficult to follow so the focus was changed to each individual's story. Later deliberations led to the conclusion that a style of reportage better reflected the method used to gather and record the evidence, so out went the tables.

As a general point the participants looked forward to the visits and saw the process as a special treat. This was brought home, very starkly, when on one occasion Gary T was ‘punished’ for bad behaviour by not being allowed to join the number sessions. He tried desperately to demonstrate his desire to join the sessions by repeating the activities that he had been engaged in during the previous sessions.

During conversation Dr Perks of the University of Birmingham described a learner who could only access numbers through music and rhythm. It was decided to adopt this approach in an attempt to test cardinality and ordinality of non-concrete objects. Drumbeats were used to explore these skills with the four participants. The reasoning was that it moved from the tangible to a more transitory form of quantity and therefore was a possible step towards an abstract concept of number. However, subsequent reading made this a questionable activity as some of the learners were not yet skilled enough to achieve this. It was potentially more fun and engaging than counting tennis balls in and out of a bucket and therefore had a novelty value that was potentially exploitable (Paterson, 2001).

The protocol was to use two drums, one for the participant and one for the observer; firstly the observer would ask the participant to hit the drum a number of times and then secondly to count how many times the observer hit the drum.

On 11th May the basic tests of McConkey were carried out using drumbeats and a feely box in an attempt to see if other methods could open the door to assessing the learners' numeracy.

Gary A

Firstly it was explained to Gary that he was going to count different types of things today, things he could not see or touch. He was going to count drumbeats. When the drums were produced he was interested and engaged. The drum had this effect on all the participants.

"Please hit the drum …"

For the first test Gary was asked to hit the drum a set number of times; the observer demonstrated to him. "If I ask you to hit the drum three times you do this Gary." The drum was hit three times to an even beat. This was to encourage Gary to beat with clear gaps between beats to ensure there was no error in the counting and recording.

"Please hit the drum four times." Gary hit the drum four times.

It was not indicated to Gary whether or not he had been successful, as it was believed that although this would have been useful in teaching and when reinforcing, when testing it may change behaviour, especially after a failure. One could argue that the test becomes so different from normality for the participant where behaviour is praised or censored that the participant does not know how to respond. Without feedback there is a risk of early boredom or disengaging from the task.

The drumming

“Please hit the drum seven times.” Gary hit the drum seven times.

“Please hit the drum eight times.” Gary hit the drum eight times.

“Please hit the drum ten times.” Gary hit the drum eight times.

“Please hit the drum ten times.” Gary hit the drum eight times.

The intension was to check whether Gary had misheard, but as the instruction was repeated three times he inevitably began to realise something was wrong. This was a disappointing error in the administration of the test, emphasising the need to consider situations where errors may occur. By rechecking in such a way there was an effect on the results. A better protocol would have been to return to a range in which Gary was successful and to repeat a successful number four, seven or eight and then return to the number ten. In this way there would have been little indication of any mistakes. The importance of being fully prepared was not lost as well as the need to attempt to predict how the observer’s behaviour and the protocol impact on the participant’s behaviour. It is impossible to predict every possibility but this was a rather obvious possibility.

“Please hit the drum ten times.” Gary hit the drum ten times.

“Please hit the drum twelve times.” Gary hit the drum ten times again.

Implications

This test most closely matched the ‘give me’ test. Gary did well on this second attempt at the test, which took place on 27th April 2006, being able to give the tennis balls up to and including eleven.

Gary was now demonstrating good counting skills and within this range excellent mastery of the elements that make up counting. This indicates that he can move beyond the mechanism of touch counting (Fuson et al, 1982), and he was demonstrating that he had a sound understanding of the cardinal principle and possibly abstraction (Geary, 1994).

“How many times did I hit the drum?”

It was explained to Gary that the observer was going to hit the drum and wanted him to tell him how many times the observer had hit it. The observer demonstrated that he hit the drum three times and said “I have hit the drum three times”.

The observer hit the drum four times. Gary then counted to ten; the observer made no comment.

The observer hit the drum twice; it was considered that this was in a very achievable range.

Gary again counted to ten.

It was not clear whether the instructions were clear enough and a demonstration was necessary. It was decided to give Gary a strategy to

achieve that he would not have developed himself. It was suggested to Gary that he should count aloud with the observer and stop counting when the drumming stopped. This was done for ten drumbeats. Gary was visibly pleased with this and found it fun as it was novel (Paterson, 2001). He was now ready to begin again.

The drum was hit twice and Gary said two.

The drum was hit four times. Gary stayed silent and when prompted said three. Again Gary was encouraged to count aloud, as this was the only indication of whether he was counting or not.

The drum was hit four times. Gary said four.

The drum was hit five times. Gary said five then he expanded “that is wrong”. He was asked what the right answer was; he tentatively suggested three, but it appeared that he knew that was also wrong.

This showed that Gary had sufficient understanding of the cardinal principle to realise that he had made a mistake. It also showed a level of confidence to express his belief that he had made an error; his self-correction was so swift that it was probably not a response to any non-verbal cues from the observer.

Gary continued with the test but did not have any success above five.

This demonstrated that Gary could count abstract objects with consistent success to five, giving a good starting point for intervention.

The implications for Gary

During this test Gary demonstrated that he required a strategy to be successful; for him it was to count aloud, a verbal type of touch counting. On the occasions when he did not count aloud he was always unsuccessful. The ability to recognise an error in the number given or counted out and the actual number of beats demonstrates the beginning of understanding the concepts of cardinality as opposed to rote counting (Fuson et al, 1982). His inability to correct the error demonstrates the lack of stability of this skill. It was possible that after Gary made his mistake he was never confident enough to engage fully with the test and was happy for the test to end.

Concentration appears to be a problem for Gary. His errors are not consistent; therefore, developing a strategy to cope in everyday life will be a problem. Gary's strategy works well for him with small numbers but he cannot recognise errors in larger numbers, a possible error in carrying the numbers in his head (Fuson et al, 1982). Given more time it would have been interesting to investigate where Gary's limit of stability is in real-life situations and attempt to increase his useful numeracy range.

The implications for the test

Gary's recognition of his error but his inability to correct demonstrates the usefulness of this test as an extension of McConkey's tests. With solid objects a recheck is possible, assuming the group of objects has been kept distinct from any others. In this test the transient nature of the beats that the participant is required to quantify demands a greater level of stability of the

cardinal principle (Sarama & Clements, 2009). It was important to be mindful of the participant; building Gary's confidence back up may have been a better strategy than pursuing a right or wrong answer approach. Greater attention was required to the subtle interplay between the researcher and the participant and an anthropological approach would have helped.

Testing Arabic representation

It was explained to Gary that he would be shown some numbers and that he was required to hit the drum that many times.

The number four was held up; Gary hit the drum four times.

Then six; Gary hit the drum six times.

Gary had carried on counting aloud as he beat the drum with no prompt. It was decided to push the boundary and show an eleven. Gary counted out eleven beats; unfortunately he had not counted the first drumbeat so actually hit the drum twelve times, a common error in the first stages of counting objects (Fuson et al, 1982). He did not indicate any recognition of this error.

The number eight was held up; Gary hit the drum eight times.

Then number three; Gary hit the drum three times.

Then a number seven; Gary hit the drum seven times.

Then number six; Gary hit the drum four times. On this occasion he did not count aloud.

He was reminded to “count out loud”.

The number two was held up; Gary hit the drum twice.

Then the number three; Gary hit the drum three times.

Then the number three; Gary hit the drum four times.

The implications for Gary

It is possible that Gary did not expect the same number in succession so when he came to three he felt a necessity to carry on counting. It would have been desirable to repeat the test on another occasion as Gary had now ‘failed’ twice and he was disengaging from the activity. However, the fact that he now knew that two identical numbers might appear consecutively affects the validity due to prior knowledge. It does, however, indicate that Gary may have a problem with change to routine and this will need extra planning for if involving numbers.

The number two was held up; Gary hit the drum twice.

Then the number five; Gary hit the drum four times

Ordering Arabic numerals

One of the criticisms of the Arabic number test had been that it was a naming exercise rather than a numerical exercise. The test was a measure of neither the ordinality nor the cardinality of the number. It is useful to be able to use numbers as ordinal numbers, from a practical point of view – look at the

picture on page five, sit in the fifth seat – but also as an introduction to the number line and the uniqueness of a number's position on the number line.

Gary was given a selection of cards with all the Arabic scripted numbers up to twelve, with some duplicates. He did not succeed in placing any of the cards in any sense of order. They were laid out in the order of

12, 11, 3, 5, 10, 2, 1, 4

It was not clear whether Gary had no idea of the order of the numbers or needed help in understanding what was required. It was decided to prompt him; however, when Gary was asked which number was number one he held up three and picked up one for two. On the two previous tests involving Arabic representations (10th January 2006 and 27th April 2006) Gary had made no errors with all twelve numbers: this was puzzling.

Gary was asked to count out loud as he laid out the cards as this strategy had worked quite well with the drumming.

He held up one then held up two but named it as four; he then, silently, held up three then one for four. Too much choice was possibly making the test too confusing for Gary. Duplicates had been chosen to stop the test becoming easier as the numbers were used up; the test is obviously simpler when you only have to order the nine and ten because the preceding eight numbers have gone. Earlier errors can be signposts; if you are left with five and ten then it could indicate that you have made an error with the five before and need to rectify this. The results here indicated that Gary could not cope with the exercise. By reducing the number of cards to five the test may have

worked but Gary was already showing signs of agitation so it was decided to move onto the next test. It was not clear whether non-verbal communication had led Gary to realise he was lacking any success; there is a problem with being an impassive observer when dealing with participants with learning difficulties. Generally participants will relate differently to the observer in that role and the expected behaviour of the 'lab coat wearer'; however, the participant with learning difficulties may not respond well to an observer who is not interacting as normal. Tensions will also be generated by anyone undertaking action research if the participants are unsure which role the researcher is functioning in at any one time, be it teacher, manager researcher or observer. This is a possible flaw of this type of research and needs to be recognised by the researcher and handled sensitively, if it is not to invalidate the research results.

Whether the problem was one of the duplicates or the frustration after the previous drumming test or from any other actions could not be ascertained nor could any way of investigating be thought of. This type of research was revealing its frustrating side; there was plenty of planning, plenty of testing and plenty of reflecting but it was generating more questions and the number of questions were growing exponentially.

The implications for Gary

It is possible that Gary cannot order the Arabic numbers up to twelve. If this is true then there are practical implications for his use of a clock and telling the time and measuring. He will need either to learn this sequence as he has the sound sequence or to have other strategies developed to help him function.

He will also have problems with numbers as ordinals (Sarama & Clements, 2009).

The implications for the test

This is a good test of ordering skills. There is still a lack of cardinal or ordinal quantity associated with the representation, but it can be used to identify a lack of understanding of the qualities of the order of numbers. If a participant knows the number names in order and the names of the Arabic representations but can not order the written symbols this could indicate a lack of transference of properties from oral to pictorial representation. This is not a problem limited to those with learning difficulties but has manifested itself in speakers of second languages, as demonstrated by the Greek patient struggling with German numbers (Proios et al, 2002).

Identifying by touch not sight

It was decided to move on to test whether Gary could identify quantities using his sense of touch. A small number of cubes were placed in a ‘feely box’ and then Gary was asked to say how many cubes there were inside the box using his sense of touch only.

The test was started with two cubes; Gary felt inside the box and said “two”. This was a very positive start and Gary was again happy with his success.

With four cubes, Gary said “three”.

With three cubes, Gary said “three”.

Five was tried and Gary said “three”.

With two Gary said “two”.

With five cubes, Gary just kept moving them around inside the box; the observer spied into the box at this point. Again, this is behaviour found in children who had not fully mastered the skill (Fuson et al, 1982). One cube was removed but he continued just moving the remainder around; three more were added and he just continued moving the cubes around the box. Gary was asked why he was not saying how many cubes there were. He said he didn’t know how many there were. A strategy was suggested to Gary; it was explained that he only needed to count each cube once. He nodded. This test most closely matched the ‘give me’ test. Gary did well on his second go at the test, which took place on 27th April 2006, being able to give the tennis balls up to and including eleven.

Gary was now demonstrating good counting skills and within this range excellent mastery of the elements that make up counting.

Gary was now demonstrating good counting skills and within this range excellent mastery of the elements that make up counting (Gelman & Gallistel, 1978). This was demonstrated in full view and then he was shown that it was wrong to count any of the cubes twice. He had a go and counted eight cubes correctly. He was asked how he would know he had only counted the cubes once if he could not see them. He did not know. He was shown that by moving the cubes to one place only once (Gelman & Meck, 1986; Fuson et al,

1982) they had been counted and this was accompanied by counting out loud. He had several goes and appeared to have mastered the technique.

Two cubes were placed into the feely box and Gary was again successful with this low number of objects.

With four cubes in the feely box, Gary said nothing. He was asked how many and he said he did not know. The exercise was repeated with four cubes and he was reminded of his successful technique; he counted out four.

With five cubes in the feely box, Gary said nothing again. He was prompted and he counted seven.

The session ended there.

The implications for Gary

Gary's reluctance to give an answer and just to move the cubes around strongly suggests that Gary is, like most of us, driven by success. When there was a risk of failure he postponed rather than committed to an answer, hence the movement of the cubes in the box. An alternative suggestion is that he was never confident that he had found all the cubes; therefore, he was never at the end of the task. He continued with the search even though it was unreasonable that he had not found all the cubes, it being after all a small finite space in which to search. Even with a strategy, moving the cubes to a set place, he did not have the confidence to give an answer. The need for success is a more probable explanation than him just playing with the cubes, as is a problem with children (Fuson et al, 1982).

Implications for the test

The observation notes stated ‘this has ceased being a number test and is now a test of his ability to grope blindly’; this comment is an indication of the frustration felt with the process rather than a comment on Gary’s performance. As an observer I had become emotional about the testing and the interaction of the participant with the tests rather than the detachment I had considered necessary for a good researcher to have. I cannot measure how much my emotions impacted on Gary’s tests, even though I felt I did not give overt signals of frustration; subtly my behaviour must surely have influenced him. I can only note this.

25th May 2006

The previous tasks appeared to indicate that Gary had not made the connection between counting the number of objects in a group correctly and attributing a definite quantity to that group of objects, cardinality. Although he appeared to have a good grasp of some skills, one-to-one correspondence, the cardinal principle, order indifference and abstraction, his lack of consistency with these did not give him the ability to use counting effectively. These counting skills are used to measure child development (Fuson & Hall, 1982) and may be part of the process of maturation. Gary’s inability to attribute cardinality may indicate that the skill needs to be developed; the assumption that the participant will know that the last number counted corresponds to the quantity of objects in the group may not actually be correct. Gary’s inability demonstrates that this is not true for everyone and

may indicate a stage of development where the mechanism of counting objects is mastered but true cardinality is not (Fuson & Hall, 1982).

Quantity

Another test was required to examine Gary's ability with cardinality and ordinality. It was decided to use counting blocks to assess Gary's ability; the test required Gary to place sets of counting blocks in amount order. The counting blocks were made up in columns 1 to 10 and arranged randomly on the table.

Gary was asked to lay out the blocks in order, starting with the smallest and going up to the biggest. Gary started to combine the blocks and make them longer, again a common problem with children taking these types of test (Fuson et al, 1982). The observer intervened. This was a mistake; as noted in previous encounters Gary worked best without any type of correction. The intervention clearly distressed him and the sensible course would have been to allow him to play for a while with the blocks to create a relaxed atmosphere. If this had also failed to work then the test should have been stopped, allowing Gary to relax and become comfortable again with the observer and the testing environment. This, although not guaranteeing that next he would be fully engaged, could still be viewed as a positive experience by Gary. Due to perceived time pressure neither of these actions were taken; there was limited time available with the participants during that session and only one more session with the learners due to the demands of the curriculum.

Gary had misunderstood the intervention and started to dismantle the cube columns.

The observer intervened again and laid the columns out as

6, 8, 9, 3, 10, 7, 5, 4, 2, 1

Gary was asked if he could lay them out in order.

“No” was his answer. It should be noted that his tone was one of a matter of fact, not one of frustration, anger or belligerence.

The notes stated that it was expected that Gary would be able to handle this many sets but that maybe it was too confusing to use so many. It was possibly too daunting for his first encounter with this test, even though his counting ability was skilful enough to predict greater success at ordering (Mix, 1999).

As with some of the other tests a strategy is required to have success and to make order out of the apparent chaos. Imagine you are faced with a thousand-piece jigsaw with no picture to aid you; you would either need a strategy to succeed, all the edges or common colours, or you may just be put off trying before you start or very early in the endeavour.

An attempt was made to guide Gary with a strategy of starting with the smallest and working up.

“Which is the smallest?”

Gary pointed to the column with only one cube.

“Which is next?” If you put yourself in Gary’s place you can imagine his problem: what was being asked for? Was he being asked for the next column, which was six, the nearest to him, or the next column of two, both next to the one column and the next in quantity? The language used was potentially confusing.

Gary answered the imprecise and unclear question by picking up the column of four.

“Are there any smaller than four?” he was asked.

“Yes” he replied confidently.

“Which one?”

Gary became visibly tense. There were after all three smaller columns and not one smaller one as the question may have indicated. From a pragmatic semantic point of view the question was absurd; there was a need to be more careful with the choice of language.

“Are there any smaller?” The observer attempted to keep relaxed and appear that the answer did not matter. However, it obviously did or it would not have been repeated.

Gary answered again “Yes” and pointed to the column of four.

It was decided that a new approach was needed and a demonstration was given of the columns being sorted into order of size.

Gary was then asked, “Are there any less than three?”

“Is it that one?” asked Gary pointing to the column of six.

The desire to express clearly the objectives of the tests undoubtedly led to even more confusion and the efforts to change the language used to express these objectives led to more bewilderment.

“Let’s sort them from the highest. Put the one that has the littlest less on the left.” The assumption here was that Gary could be struggling with ordinality but had a clear understanding of left and right so would place the columns left to right in order. As it transpired the garbled instructions of repeated negatives were understood and Gary slowly, but without prompting, placed them ten down to three in order. This not only showed his ability to deal with muddled instructions but a good understanding of ordinality, especially as most ordinality tests only require the participant to compare two quantities (Sarama & Clements, 2009).

The words had been unconsciously changed, from “highest” to “tallest” and this was recorded in the notes. Gary was asked “Do you think they are in order from the tallest?” This was an attempt to see whether Gary was attributing quantity to the columns or making patterns without giving any particular numerical property to the ordering. Gary had sufficient counting skills to use cardinality to help with this task (Mix, 1999); an opportunity to investigate if he was using counting was missed and that if he was reluctant to use counting which of the many explanations gave rise to this reluctance (Sophian, 1998; Pascual-Leone, 1978; Cowan, 1987).

It was noted that ‘Gary does not understand the word “order”’. Other researchers had used the terms bigger and smaller with success with three-year-olds (Sarama & Clements, 2009). The language being used was beginning to inhibit the testing of numeracy and was beginning to test Gary’s vocabulary.

“Which is the smallest?” Gary could not indicate which was the smallest.

The implications for Gary

Gary demonstrated some form of ordinality yet could not order consistently. The possible causes were: the language used in the test, he did not appear to know how to order, which is unlikely, or the test lacked meaning for him. In a desire to give motivation to Gary it was decided to use sweets on the next visit. Gary was asked if he liked chocolate and he became very enthusiastic. This appeared to be a way to eliminate boredom from the test.

The implications for the test

This test illustrates well the tension between the freedom that action research gives in adapting quickly to changes in circumstances and the possibility to wander away from the point of the investigation. By being reactive the way was somewhat lost, and in attempting to find words to support Gary and the test the language actually became more confusing. The action research spiral was being used in haste and not enough time was being spent reflecting and replanning. Thorough planning remains important in action research predicting possible outcomes and threats to the research and how best to deal with these will make for a better research environment in which the

researcher and participant can explore the issues. It is obviously impossible to predict all the possible problems but the more thorough and thoughtful the preparation the less likely one is to end up confusing the participant and invalidating the test.

Better planning may have helped with the impact of the language; in normal conversation we interchange words seamlessly without losing the meaning of the speech. Here tallest, biggest, longest and highest potentially all meant the same quality of the column. What these words meant to Gary was not fully considered; only that they were interchanged in an attempt to help him gain an understanding of what was being requested. A little time spent finding out what Gary understood by these words or an explanation of what was intended by the use of these words would have helped in removing some of the confusion. Using the word ordering in this specific case was also thoughtless. If consideration had been given to where Gary could have possibly come across this word, a restaurant or pub would have come to mind or when someone is being told to do something by another person in authority. Neither would make sense to Gary in this context. A review of the language used in the tests may show an adverse impact on the tests and recording of the dialogue would have been beneficial.

The recording of some of what had been said had highlighted some of these potential threats to the validity of the tests. It is as important to know what doesn’t work as well as what does, and to use this knowledge to improve the processes.

8th June 2006

It was decided to use chocolate ‘Heroes’; the participants were given the choice of either a plate with the most or a plate with the fewest chocolates, then they could choose a chocolate of their choice as a reward. Only one type of chocolate ‘Hero’ would be used so that the participants’ personal preference for a particular chocolate would not be a factor. This was necessary as it was intended to ask some participants which they would choose if they wanted the most chocolates. This was intended as a more considered question after the last session where there were problems with the language and with communication and to limit the choice to a more manageable set of options (Sarama & Clements, 2009). If the participants were to choose their favourite or avoid the unpopular choices then this would skew the results. It had been considered rewarding the correct answer with the whole plateful of chocolates but this was discarded as the participant was more likely to choose the greater number and also the rewards would quickly run out.

The choices Gary made

At the last minute and without any planning it was decided to try and ascertain whether the types of objects that were to be chosen had an impact on performance. It was decided to see if Gary would be as successful with other objects that were available in the classroom; he unsuccessfully chose between groups of pencils, coloured pens and leaflets. However, when it came to the chocolates Gary was extremely effective. He successfully chose three over one and when the plates were reversed, necessary to eliminate

spatial positioning having an influence, he again was correct. He was also successful with six over four, eight over two, nine over one and seven over three; even when the numbers were similar as in five over four and seven over six. He appeared to assess the amounts without counting just by observing the group size; however, as this was over the upper limit of five for subitising it is unlikely (Starkey & Cooper, 1995). He did demonstrate other aspects of subitising confidence that Taves noted (Sarama & Clements, 2009) and speed for Saltzman and Garmer (Sarama & Clements, 2009).

Gary did have problems when the groups were the same size; when the groups both contained two and another time when they contained five. This was interesting as it was outside Gary's expectation as neither group fitted the question. Given the alternative of 'or are they the same' he may have had more success.

Ordering

Three plates of chocolates were laid out and Gary was asked to put them in order from smallest to biggest. It was expected that Gary would remember from the previous session that ordering was nothing to do with an order of food at a restaurant or to give the chocolates a command but to place them in ascending quantity. He did none of these; he tidied up the plates and laid out the chocolates on the plates in a systematic order, swapping chocolates from plate to plate, a type of behaviour he had demonstrated before (Samara & Clements, 2009). Gary had put the plates in a state order.

“Which is the smallest?” Gary: “This one’s smallest.” He picked up one chocolate bar.

The plates had nine, two and five chocolates, respectively, on them from left to right.

“Which plate has the smallest number of chocolates on it?” Gary successfully indicated the plate with two chocolates on it.

“Which plate has the biggest number?”

Again Gary was successful.

“Which has the middle number on it?”

Gary picked the middle plate not the one with five on it.

The plates were shuffled and Gary was asked “Which plate does not have the biggest or the smallest number of chocolates on it?”

Gary just stared at the plates.

“Is it this one?” The plate with two on it was pointed to, which was on the right of the other two plates.

“Yes.”

Smaller to bigger was explained and demonstrated.

“Can you put the plates from the smaller number of chocolates to the biggest number of chocolates?”

“Only move the plates.” This instruction was given to stop Gary from moving sweets from plate to plate again, demonstrating the problems with this type of test, which can encourage distraction by its very nature (Samara & Clements, 2009).

The plates had one, eight and four chocolates on them. Gary just stared at the plates.

The session was ended and Gary had a few more chocolates.

The implications for Gary

Gary clearly had an understanding of smaller and bigger amounts when it mattered to him. His successes with the chocolates indicated this; his inability to cope when there were the same number on each plate probably indicates that he could not make sense of the situation rather than not knowing they were equivalent to each other. He was clearly using subitising and numerocity to make his decisions (Ansari et al, 2005) as the numbers ranged from either side of five (Starkey & Cooper, 1995).

A new test will have to be devised where Gary has the desire to succeed and the concept of equivalence is explored. Also, he appears to know the biggest and smallest but does not comprehend ordering. This was a small sample with which to draw this conclusion safely and further work to explore his understanding is required.

The implications for the test

If, as in Gary's case, the participant has a clear understanding of the meaning of the words bigger and smaller this is a good method for testing the concept of bigger and smaller groups. This may also introduce or reinforce the concept of a bigger or smaller number and hence quantity.

It was decided to use three plates and not four as there was a concern that too many choices would cause problems as before; however, again the use of language, 'middle', created confusion and impacted adversely on the test.

Subsequent consideration of other words and phrases such as between, centre and intermediate all seem equally inadequate. However, these tests do show how important language is in numeracy and raise the question of how often learners fail through an incomplete understanding of what is being demanded of them. Mathematical language is full of words that have very specific definitions within the field of mathematics and have a less precise meaning in lay speech; 'average' has three meanings in the world of mathematics, and 'speed' and 'velocity' are not interchangeable. However, it is not the lack of precision that is the issue with the language of these tests but ironically the richness of the English language. Words can have several meanings, as in the case of the word 'order', or words are interchanged, even within the same sentence, and still hold the same sense. In general use greatest, biggest, largest, longest and tallest could all be used to denote the column with the most cubes in it. The potential for confusion is enormous, massive, huge and even vast. When dealing with learners such as Gary it is important to ensure that they understand what is expected. In this case there

was a tendency to pepper the learner with words in a scatter-gun approach in the hope that one of the words would be understood. Although this was done in the belief that it would help and support the learner it could also be destructive as the observer frustratingly lists the possible words and rephrases everything, developing an atmosphere of failure (Kazdin, 1977). It had become apparent that there was a need to be more precise in the language used in teaching mathematics: to take time to negotiate with the learner what is expected; what words will be agreed upon to use and what they mean to the learner. For this to work effectively it is advisable for the teacher to allow, in the early stages, the learner greater parity in their relationship and to value the learner's choice of words, even when the common usage is compromised. It is sensible to use these words until the concept is stable then introduce other words that are used in everyday language.

Gary T

The tests had been adapted and changed in response to the work performed with Gary A and the previous problems demonstrated by Gary T. Again there was an attempt to use other techniques, including drumming, and what were hoped would be meaningful objects to examine this Gary's numeracy skills.

11th May 2006

This session took place immediately after Gary A's session and therefore was modified to accommodate what had been learned from the work with Gary A. There was also an interest in Gary's pronunciation of the word seven.

Arabic numerals

Gary was asked to repeat the ‘give me’ test, using Arabic number representation; knowing he would count aloud, this give the opportunity to test the pronunciation of seven when the numbers were seven and above. After the initial effort when Gary failed to give me four tennis balls he was successful on all attempts. The numbers requested were four, ten, seven, eight and eleven; however, he pronounced seven correctly on the ten, eight request but as eleven on the seven, eleven requests.

Gary appeared desperate to please and was making a big effort to pronounce seven correctly. It was thought that seeing the numbers seven and eleven next to each other and asking him to pronounce them would reinforce the difference for him and thus enable him to be more successful in his pronunciation.

The numbers seven and eleven were held up and Gary was asked to say the name of each number.

Gary made a big effort to say seven correctly.

The test was repeated with four, ten, eight and eleven. Gary was successful at pronouncing seven on each occasion; he appeared to make a great effort to get this right. He was rewarded with much praise.

The implications for the test and Gary

This showed that with the right level of support and preparation Gary can overcome his mispronunciation and the associated problems. By reinforcing

his success, highlighting the differences between seven and eleven and giving the opportunity to practise and master the pronunciation Gary could succeed in always getting it right. This would have a very positive impact on his life when he needs to use the word seven.

The test itself was very individual to Gary's needs but demonstrated how general tests can be adapted to meet individual needs (Nye et al, 1995).

Beating the drum

Gary was asked to say how many beats were beaten out on the drum.

First there were two beats. Gary counted out aloud and stopped at four. The drumbeats were repeated with two again and Gary counted aloud after the drumming had stopped; this time he stopped at two. For the next two attempts beating out three drumbeats, he counted after the drumming had stopped and got the number of beats wrong.

Gary was asked to join in and count as the drum was hit. This he did on the first attempt. On three beats he was successful then with two he again said three, and with the next number, four, he started counting after the drumming had stopped, a common error when counting physical objects (Fuson et al, 1982). He was reminded to count as the drum was hit; he did count as the drum was hit but he counted on to four and six, respectively, for the next two attempts when the drum was only hit three times.

It was suggested to Gary that he only counted the times the drum was hit and no more.

Beating out two, three, two and four was repeated. On each occasion Gary overcounted, again an error found when the skill is not stable when counting objects (Fuson et al, 1982).

Gary joined in with the observer in counting as the drum was hit; he still overcounted.

The implications for the test

Gary's inability to master this skill indicates how difficult it is to move from the concrete to the more abstract. Even though the sound is real, the transient nature makes this a useful measure of how well established the cardinality skill is (Fuson et al, 1982). Counting beats is a higher-level skill than counting objects as there is no opportunity to restart or recount the beats. There is also the need to be able to stop counting quickly, which requires a good understanding that the last number counted gives the number of beats (Fuson & Hall, 1982). When counting the beats there is a need to hold the number of when the beats stop in our memory and not be distracted by the subsequent numbers. This is even more difficult than keeping track of objects being counted, which can be a problematic developmental stage (Alibali & DiRusso, 1999). If we overcount we need to go back quickly to the right number in the order, in effect performing a quick mental subtraction. This ability requires the mastery of the stable order principle at the bi-directional chain level (Fuson et al, 1982).

In conclusion, failure to perform this task may indicate problems with order stability or cardinality.

The implications for Gary

In Gary's case, as he has already indicated good order stability, his inability to perform this task would suggest that Gary has a poor understanding of cardinality and that the last object, which is difficult in his task as it is a sound, corresponds to the cardinality of the set (Fuson & Hall, 1982).

Gary joined in beating the drum

Gary was asked to beat the drum the same number of times as the observer. "Copy the number of times I hit the drum"; for the first two attempts, of two and three beats, Gary copied correctly. Three was repeated and he hit his drum four times; three was repeated to ascertain if he had misheard but again he hit the drum four times and when two was tried he again hit his drum four times.

"Listen carefully", he was prompted.

For two beats Gary hit his drum four times, for four beats six, for six beats eight and for eight beats ten times; a pattern was emerging. He was obviously adding two to each number.

Three beats were tried and he hit his drum four times, for five beats six and for seven beats ten, so there was no real pattern after all.

Beating the drum to an Arabic number

Gary was started with seven and clearly said, with no pronunciation problem, “seven”, but he only beat the drum once. The same happened with nine and four: he said the number but only beat the drum once.

A demonstration was given; Gary selected a number, five, and the observer beat the drum five times. The process was repeated with eight.

Gary was shown the number three; he said “three” and beat the drum once.

Gary was told that the observer would join in; together they beat the drum five times as the card with five on it was turned over.

Gary was shown the number three. He said “three” yet hit the drum once.

The observer joined in and they were successful with four.

The implications for Gary

From the former test with the tennis balls and Arabic numbers it would appear that Gary can count out quantities and has mastered cardinality (Gelman & Meck, 1986); however, the move to a non-concrete object demonstrated that Gary has not fully mastered the concept.

Whether there is an element of delay in his joining in, which leads to less success, is not clear (Fuson et al, 1982) and would require video and time freezing to help identify this behaviour.

The implications for the tests

It would appear that this is a good measure of the mastery of cardinality and the participant's ability to count all objects. However, there is possibly an element of learning what to expect (Pugh, 1971). Most learners will have spent much time at school and at home counting solid objects and be comfortable with the procedure. A new procedure may require some getting used to until it is truly a measure of the skill being tested. To this end an adoption of the test for many learners and a measure of the number of times required for mastery would be useful. This would again show whether it is possible to master the mechanics of the process without the understanding (Munn, 1994; 1997; Fluck & Henderson, 1996).

Using the counting strategies

Gary was asked to count out loud as he hit the drum. Gary made an error on his first attempt; he only started to count on the second beat, so he beat out four beats yet said "three". After this he was totally successful with three, five, seven, four and eleven; his pronunciation of seven was also correct.

Counting aloud

Initially the counting-aloud strategy was used to detect what was going on, indeed whether counting was taking place at all, and if it was happening correctly. It appeared to be a useful aid to the participant.

Feely box

Gary was successful with two cubes and three cubes; he was not with five then four and then five.

Moving the objects to a set area within the box was demonstrated to him.

Gary followed this strategy but still said “four” for five objects and “four” for six objects. The test was stopped as it was clearly a poor test of the participant’s understanding of cardinality.

Ordering Arabic numbers

Gary had been observed in a numeracy lesson performing the test of ordering the Arabic numbers with some success; this had taken place prior to the tests as part of a background-gathering exercise. What had hindered his total success, on that day, was the teacher failing to identify what strategy he was using. He was laying all the numbers out on the table first, before putting them in order; this worked for him even though it was not the preferred strategy of the teacher. She wanted him to use her strategy and held an expectation that Gary would be able to approximate the position of each number in an imaginary array as he turned the number card over. This is a higher-order skill than just placing numbers in order and led to Gary’s partial failure. Taking this into consideration it was decided to allow Gary to use whatever means he wished to lay out the number cards. Gary took his time and laid out the cards then put them in order.

He clearly could order Arabic numerals.

8th June

Gary was asked which group had more sweets in it, demonstrating a very poor choice of words again: plate would have been better.

“This one.” Gary very tentatively pointed to the plate with five sweets, which was correct. Two plates were laid out, one with nine on and the other with two on. “Less sweets?” was asked, using intonation to imply that it was a question. Gary answered correctly by indicating the plate with two sweets on it. This carried on with three and two and the same question “less than?”; Gary pointed to the three. The plates were swapped over so a different number was closer to him and he was asked again “less than?” Again Gary pointed to the three. Again the question was repeated and again Gary chose the three. Again and he chose the two.

It was decided to finish, as Gary had clearly been confused. As had been promised Gary was allowed to choose a plate of chocolates. His choice was between the plate with three chocolates and the plate with only one chocolate. He chose the one with three on it; when asked “Why did you pick that plate Gary?”, he answered “because there are more”. Gary clearly knew more and less when there was sufficient motivation.

David

This is a description of the very different encounters with David: the issues of continued informed consent. It also highlights the problems of communication between the participant and the researcher and how they affected these tests.

Beating the drum

David was asked to beat the drum the number of times asked.

“Can you beat the drum David one time?”

David beat the drum many times.

“Can you beat the drum two times?”

David beat the drum many times quickly with obvious glee and enjoyment. Again this demonstrates how the test can in itself become a distraction (Fuson et al, 1982).

A demonstration was given of one and two beats, but David just beat the drum and was obviously enjoying himself.

The implications for David and the test

From this encounter it cannot be ascertained whether David does not understand the instructions, does not know his numbers or finds the activity too enjoyable and therefore distracting.

It was decided to move on.

The observer takes over the drum

David's verbal communication skills were limited; therefore, he could not express himself clearly. To eliminate any error David was asked to use the tennis balls to indicate how many times the drum was beaten.

A demonstration was given. The drum was beaten once and one tennis ball was held up; the drum was beaten twice and two tennis balls were held up.

When David indicated he was ready the test started.

The drum was beaten once. David got all the balls out of the bucket, saying randomly "one" or "two".

"Let's put them back David; if I hit the drum once you put one back like this."

The drum was beaten once and one ball was put in the bucket as a demonstration.

Then two drumbeats were played and two balls were put in the bucket.

Now it was David's turn. The drum was hit once; David put all the balls back in the bucket and kept saying "two", whatever number of beats were beaten out on the drum.

The drumming was stopped; "Put two balls away when you say two." He did for the remaining balls.

The implications for the test and David

From the way the test ended it may be concluded that David understands the concept of two. However, David was observed in a numeracy lesson being rewarded with praise by a teaching assistant whenever he identified two objects and repeated the word two. No other number of objects was shown; therefore, David learned that when he said two he was rewarded.

21st May

It was hoped to use the feely box to assess whether David could distinguish between greater or lesser stacks of blocks.

David was asked “What is in the box?”

There were two columns of cubes, a one and a two. David reached in and let out a whoop of surprise and delight.

David unprompted peaked inside.

“Look inside, David. Can you get me the biggest out?”

David handled both but retrieved the single cube.

“Is that the biggest?”

David looked inside and shrugged his shoulders.

“Is this one bigger than the one you have?” A column of two was held up.

David responded by shrugging his shoulders.

A three and a one were placed, hoping that the greater difference would help David distinguish between the two columns. David was asked to pick the biggest, but he just kept groping in the box and did not get either column out.

He was prompted, “David can you get me the biggest out of the box?”

Eventually he handed over both columns.

He then started to place all the cubes into the box.

He was asked “Can you put the biggest into the box?”

He put both the three and the one into the box.

The implications for the test

This was an improved use of the feely box rather than having the participant attempt to count the objects inside and the problems associated with this. This test just required the participant to be able to distinguish between two sizes of object through touch rather than the visual tests used on children with learning difficulties (Paterson, 2001). The possible advantage over having the objects on display is that the participant, as in David’s case, finds this more engaging with an element of adventure. However, on reflection, it did not necessarily test subitising or numerosity but difference in length. Although the bigger of the two columns was made up of several more cubes the participant may not realise it could be perceived as a whole. If a learner could recognise the differences in size this would be a way of introducing cardinality; first

recognise the difference in size then measure by counting the constituent parts, in this case cubes. This would show that a larger object has more constituent parts and that it has a unique number attached to it. In this way the learner would eventually learn, if this is a central process (Fodor, 1983), subitising as well as numerosity.

Again there were issues here with the language used. Asking which *one* is larger was potentially confusing to the participant, especially when one of the choices had one unit in it. It would have been clearer to the participant to use the definite article *the*, as would being less polite: “give me the biggest” would have been a more effective statement. Using English etiquette a question had been used, but as the participants were also British it is likely that they realised it was a request rather than an interrogative statement.

8th June

The sweet test

“Which plate has most sweets on, one or two?” was asked. Plate one had one sweet on and plate two had two. Nothing appeared to have been learnt about the language being used from the previous test.

Each plate was pointed to in turn.

David replied “three, five, two, one ….” David kept saying random counting words.

“Remember David you can have the sweets off the plate you choose.

Which plate has the most sweets on?”

David “two”.

“You can have that plate of sweets.”

I felt relieved that David had had a breakthrough.

David hesitantly took the sweets; pleased with success David kept repeating the word “two”.

The implications for the test and David

On reflection a situation had been created where David would most likely be successful without any understanding of quantity. The plates had been identified as one and two: ‘this plate or this plate’ would have been sufficient. Using numbers in this way required the participant to be able to use numbers as identifiers; with this level of learner it is necessary to be careful with what identifiers are used. Whereas left or right were not used with David as identifiers as it was assumed that these were undeveloped concepts, red and blue could have been used after a little colour testing. Being able to recognise colours is part of the test for the Adult Core Curriculum Basic Numeracy Milestones; therefore, using something as simple as colour can also be problematic. In David’s case, by referring to the plates by number, the test had been compromised and referring back to the praise he had received in the numeracy lesson he was most probably going to say “two”.

Causing no harm; continued consent

A member of staff had heard what form the tests were taking and how they involved sweets; she came into the room to warn that David was diabetic. David's records were checked and fruit was deemed a safe alternative.

This incident demonstrated a fault in the protocol and a possible breach of ethics; although permission had been gained from David's parents to investigate his numeracy skills, they had not been informed of any changes made to the methods of investigation. This raises the issue of whether it is necessary to inform those giving consent of every change made in the action research spiral. If all the parents had been informed as the changes took place there would have been two positive outcomes: one, a diabetic would not have been offered chocolate; and two, the issue of ownership of the research and its usefulness would have been addressed. Consequently it is felt that there is a necessity to update continually those involved of the progress and changes taking place so they have some ownership of the knowledge and can continue to consent to the process.

Oranges not sweets

After the staff's timely intervention the plates were cleared of sweets and replaced with orange segments. Both plates were then placed back on the table.

David took one plate of segments and swapped it for the other plate; he then continued swapping segments from one to the other.

“Pick a plate.”

“Choose a plate.”

Firmer, more directive language was used.

He continued to move the plates and repeat “two”.

When reminded he could have the orange segments David chose a plate with only one segment on it and ate it.

This continued with David moving plates and repeating the word “two”; when prompted he would select the plate with one segment on it and eat it.

The implications for David and the tests

David had demonstrated no comprehension of the concept of number or quantity throughout any of the tests. This implied that these tests were not useful for a participant such as David and an assessment based on observing him in his daily routine would have been more effective. The classroom-based test was attractive in that it was possible to go some way towards controlling the environment. However, the level of engagement from the participant may have been questionable as the tests may have appeared meaningless or confusing. The problems of observing in a natural setting are that it is intensely demanding on the observer so can only take place for a limited time. When interpreting the causes of any behaviour two observers may reach different conclusions from the same event. However, from a numeracy point of view there are possible benefits; if a participant puts two sugars into a cup of tea when two sugars are asked for or lays out the table for the right number

of people matching the number of forks to the number of people then this would indicate number skills. This would also give an indication of functional numeracy skills to aid everyday living, which is the aim of a basic skills numeracy programme.

Mark

Here is a brief description of Mark's experiences. Due to illness and holidays he only had one session. This could be recognised as Mark's right to withdraw, or it could be viewed as participant mortality and hence impact on small-scale research.

11th May

It had been decided to address each individual learner's needs as well as attempting to develop different tests. For Mark these included developing his counting skills. He had demonstrated inconsistent results in the initial tests. A popular method in early years education is the use of the number song (DfES, 1999). A brief visit to the Internet produced a few songs that it was believed would be useful; these songs were combined with the use of the Smartboard to help engage and stimulate Mark. Two songs were used, the 'chickencount' and the 'hokeypokey'; the 'hokeypokey' had very little actual counting but was engaging. The 'chickencount' was very successful as Mark joined in with the counting words and was fully engaged.

This was found to be a complex session as an attempt was effectively being made to engage in two activities at the same time. There was a tension between being a good teacher, making the learning fun and involving Mark, and a good researcher, who at the same time was attempting to record the results. The recording took second place to being involved with the learning process and so memory over note taking was relied upon to record Mark's performance. He did join in with every rendition of the song and soon mastered all the counting words up to ten. When asked to count after the songs had finished he could remember the words in order, demonstrating that he had learnt the words as a single sequence (Fuson & Hall, 1982).

Reflections

For Mark this was an effective session. He had his memory jogged and then could use the counting words. It was felt his parents should have been advised to encourage Mark to count every day, preferably as a game; this would enable him to keep his skills up to date.

It showed how there was a need to consider ways of recording data when engaged in learning activities; an obvious solution would be the use of audio and video recording equipment (McKernan, 1996).

This was the last session with Mark as he was absent on the other occasions. If Mark had been the only participant there would have been little data; this illustrates a potential problem with small-scale research. This was a case of participant mortality, not literally, but a collection of unfortunate incidents that impacted on the data. It later became evident that Mark had sporadic

attendance and this was probably foreseeable, which raised the question of whether other students would have benefitted more from being involved in the research. Yet the advice that could be given to Mark's parents and to the other teachers would be useful to him if it was acted upon. It was deemed that this was beneficial to Mark and justified his inclusion in the research. If nothing had been found of use to Mark his participation would have been questionable and would have raised issues about participant motivation. It is important to remember that for truly free participation, if the participant wishes to withdraw then he or she has that right (BERA, 2004).

Chapter 6

FEEDBACK

This chapter describes how the information was shared with the participants, their families and their teachers and what advice would be given now in response to further reading on the topics of counting, cardinality, subitising and numerocity.

Feedback

The final cycle was closed by sharing the findings with those who it was believed made up the local community that was affected by this action research project. Dissemination of the findings to relevant interested parties is an important part of the action research process:

> Sharing the results – either formally or informally – is the real activity that bridges the gap between research and application. Communicating your results lends credibility to the process of action research …. (Mertler, 2005: p. 175)

An important point taken from Mertler was not only the need to share the findings but that it was not necessary to do this in a formal manner. This allows the information to be shared with the participants in a method suitable for their needs.

It was realised at the end of the research that it would have been better to have agreed with the participants at the outset what form would be the best way to share the findings and to agree a mutually beneficial way of putting the data to use. When considering Lewin's cycle or spiral many researchers do not give sufficient thought to how the data will be published, and time and again the spiral is left to continue with no clear conclusion to the process (Costello, 2003; deet, 2008). That the data would be shared with the participants and the extended community had been considered but not in detail, nor had the best way to 'publish' the findings been thought through with sufficient care.

It was decided to contact the parents by telephone and ask them if they would like to meet and also to offer them a short written report. As for the teachers, it was decided to talk to them individually and also add my written report to the learner's file. The teachers were offered the opportunity to discuss how to use the findings to help the participants.

After the phone calls meetings were set up with the parents to discuss the results. All were keen to receive the written report and for the results to be shared with the teachers.

The reports to parents

Mark

Both Mark's parents came in to receive feedback. It was explained that as Mark had been absent on many of the occasions there was only limited information. They were still very appreciative; stating that any help was

thankfully received. It was explained that although Mark could count this did not necessarily mean he could use numbers and that the next step was for him to put quantities to the numbers. They were informed that Mark needed as many opportunities as possible to group and name the number of objects.

The written report

Mark has limited number skills and although he can use the counting words he does not always remember them.

Being able to say the counting words in order does not mean that Mark understands them.

He can not put the right quantities of objects with the number.

I recommend that Mark finds time every day to say his number words. He especially likes songs with numbers in, and this will help him remember them when he needs them.

I also recommend that Mark spends time counting objects in small groups, up to six at first.

Thank you for allowing Mark to participate in the project. I hope this has been helpful; if you want to discuss these results further please do not hesitate to contact me.

Note: I felt it was important that the parents of Mark had some activities to do with him as when he was engaged he improved his skill level of counting.

David

David's mother came in to receive the feedback. She said that she appreciated that time had been taken with David but realised there was little that could be done. It was explained that it was felt that there was much that David could do but it would be better in a more natural setting. She has a good relationship with David's trainer (at the college). David's mother was informed that all the information would be given to David's trainer to help her, the trainer, to recognise numeracy learning opportunities while David is on his work placement and in his meal preparation lessons.

The written report

David has problems with his language skills and this makes it difficult for him to communicate his understanding of numbers.

Although David entered into the tasks it was impossible to access his number skills.

He has learnt to say the word "two", but uses it whenever there is a requirement to use a number.

I am sorry I cannot add any more to your understanding of David's number skills. If I had more time to investigate, I would observe David in his everyday activities to look for clues to his number skills.

I have shared these ideas with B… who supports David at his work placement and she has promised to look for evidence and pass this on to both you and myself. I will be more than willing to help unpick any information B… finds.

Thank you for allowing David to participate and again I am sorry the findings could not be of greater help. If you wish to discuss anything to do with the project please do not hesitate to contact me.

Gary A

Gary's mother came in and discussed the findings. She clearly understood Gary's problems with concentration and staying on task. She was very keen to find different ways to engage Gary's numeracy skills and added many notes to those that had been prepared. Her concern was that Gary was not getting as much number work at college as he had received at school and thought his skills were deteriorating; she was reassured by some of his results. She was committed to ensuring Gary improved his independent living skills. (Note: Gary has now left home and is living in a supported flat with young people his own age, with greater autonomy and responsibility.)

The written report

Gary has relatively good number skills; he knows his counting words. He can associate groups of real objects with the appropriate number. How large a group he can do this for depends on his engagement and concentration. If it is important to Gary he is very successful.

Counting through touching is a normal stage of development; for Gary to improve his number skills he needs to be able to say how many objects there are in a group without having to touch all the objects in turn. He needs to practise this skill starting with a small number of objects and gradually increasing.

Another step for Gary is moving to counting things that are not physical objects; we used drumbeats. I appreciate that having Gary drumming all the time may not be what you want, but asking him how many times something appears in his favourite TV programme would be one idea.

Thank you for allowing Gary to participate in the project. If you want to discuss anything related to the project or more ideas for how Gary can improve his counting skills please contact me.

Gary T

Gary T's mother took the opportunity to come to college and discuss the findings and Gary was present.

Gary's mother was particularly interested in his problems with pronunciation and explained they had not really considered it a problem until it had just been pointed out. She stated that they, the family, would make an effort to correct his mispronunciation in future. Gary was evidently very pleased with this.

The written report

Gary has good number skills; he can count and put the numbers in order. He uses his own methods and given enough time will arrive at a solution. I would suggest allowing him time to perform tasks at his own speed and not to jump in too quickly to get the task completed.

Gary has a problem pronouncing the word seven; he has what is called fuzzy language, so he calls seven 'eleven'. This may appear trivial but can impact on Gary's everyday life as people he comes into contact with will not know

this and in some cases assume Gary has made a mistake when he has said eleven when the answer was seven. For example “which bus do we need to catch?” The one four eleven for one four seven bus.

He may also end up with the wrong number of items, for example when he thinks he has asked for seven knives and forks and is given eleven he will know this is wrong and be confused.

I suggest that you work on correcting Gary’s pronunciation; this worked when he was on the project, but will need reinforcing at every opportunity. I suggest that when Gary says eleven you ask him if he meant seven or eleven; he can say seven when he is reminded and he will make the effort.

Gary also sometimes muddles up the words for eleven and twelve, which shows he has not yet fully mastered these words; he needs to practise these words.

Thank you for allowing Gary to be part of the project. If you wish to discuss anything relating to the project please contact me.

After the written reports had been given to the parents there was no more direct contact. However, through the participants’ college trainers, who on some mornings met the learners in their homes, the parents expressed their appreciation of the work that had been carried out. Mark was encouraged to practise his number songs and groupings and Gary T to improve his pronunciation of seven; David’s parents said they carried on as before. Gary A was engaged in counting on TV as whenever he met the observer he

informed him of how many times Dot or some other character had been on ‘Eastenders’.

The small yet positive impact on the participants’ home lives was pleasing; it was felt that it would have been beneficial to meet with the parents at the outset, as it would have increased the ‘participation’ level. It also would have made writing the reports much easier; it had been difficult to judge the right tone to be neither too technical and exclusive nor too patronising and simple. This was an important lesson on the administration of action research, to value all the participants, even those one step removed.

It was decided to feed back to the teachers and trainers, who taught and supported the participants, on an individual and informal basis. This would take more time but would gain the full attention of each teacher and trainer and enable the sharing of specific ideas. The trainers who spend whole working days on a one-to-one basis with the participants took the most interest and were enthusiastic about encouraging improvement. Many staff found the work revealing and stated that it explained certain incidents that had occurred in the past. There was an impression that this would make the teachers more tolerant of some behaviours than before. This is a positive feature of action research as the practitioner–researcher begins to look at the participants in a different way as well as hopefully those receiving the results. The subtle shift in observing behaviour in a more objective manner and hence judging the impact of that behaviour and not judging the person is a powerful argument for practitioner research. Action research, by design, requires looking at the local environment in a different way and with an objective

approach; this in itself makes the exercise worthwhile as it makes the action researcher a more reflective practitioner.

Chapter 7

CONCLUSION

In this conclusion there is a description of the main findings of the research and how they revealed the subtle and small steps in numeracy development. There is recognition of the development of more sensitive tests to ascertain the elemental steps in developing the ability to count, subitise and order. There is also recognition of how the process of research had a beneficial and transforming effect on the researcher. The need to anticipate potential problems and to prepare the participants to optimise the time together is also discussed. The strengths of action research are reviewed and recommendations given for further investigation into the understanding of numbers of the staff teaching in the further education sector.

Improved understanding of the complexity of simple number tasks

Counting

One of the main revelations of the research was the level of complexity experienced by adults with learning difficulties in dealing with apparently simple counting tasks. A greater understanding of the incremental steps by which these skills are developed would have aided in the design of tests to

pick apart the various levels of skill. There is a need for tests that can distinguish between the various early stages of learning the stable order principle (Fuson et al, 1982). This will give a better indication of what tasks can be used to develop individual skills; although both of the Garys and David demonstrated the ability to count, they are all at different levels and each one requires a unique set of tasks to help them develop. There is a need to achieve the bi-directional level of mastery as a prerequisite for more complex number tasks, such as addition and subtraction. Until this skill is developed the level of consistency with which counting on, for example, can be performed with any certainty will be low. There is a need for parents, carers and those charged with developing and maintaining numeracy skills in adults with learning difficulties to be made aware of these small incremental developmental steps and the need for mastery before any progression is attempted. This will ensure greater success as the progression will be based on a sound foundation and an understanding of realist targets.

There is a lesson to be learned from other languages (Han & Ginsburg, 2001) and although we cannot redesign the number system to mirror Old Chinese the message is that repetition is important. The advantage gained by speakers of Asian languages is the extra practice given by the number system beyond ten (Aunio et al, 2004). Increasing the number of times Gary T and Mark practise the number words will benefit them. It is also important to recognise that greater time and patience need to be given to mastering the teens (Baroody, 1992) as these are particularly difficult to learn; Gary T did display some problems with these numbers.

There is also a need for a greater awareness of the problems with moving beyond counting as an act in itself (Fluck & Henderson, 1996) and that errors will occur while this transition takes place. There will be errors such as failing to start to count with the first object, missing objects and just moving objects around without saying the counting words (Fuson et al, 1982); realisation that this is part of the learning process and not complete failure will enhance the learning experience for all those involved.

The thinking behind hierarchical interactionalism (Sarama & Clements, 2009), and the debate as to whether number skills are cognitive modules (Shipley & Shepperson, 1990; Gelman & Gallistel, 1978) encourage the idea that number skills can be developed. Accepting that these young adults are in a finished state is not supported by these developmental theories and that the state as an adult is not predicted by the developmental problems encountered through childhood (Paterson, 2001). To reverse Paterson's (2001) argument on the adult end-state giving no indication of the correct intervention strategies for the child, neither do the problems encountered in childhood give appropriate interventions to the adult. This realisation that the steps are small and require practice will make success and improvement a possibility; Gary T tried hard to improve his pronunciation and was becoming successful.

Testing the counting of objects remains important and the use of the feely box and the drum, although novel, had particular problems. The feely box was useful as it was a tactile test but did become a test of searching and of confidence that all the objects had been found. The confidence issue was of particular relevance to Gary A; again, familiarity, play and giving strategies for

success would help with this test. The drumming was affected both by its novelty and by the language used. It appeared that drumbeats were not the purpose of counting, and this concept needed to be introduced in simpler steps and with agreed terms and language.

Subitising

As a preverbal skill (Feigenson et al, 2004) subitising would have been a more suitable subject of investigation for David as his language made communication difficult. Testing all the participants' subitising skills would have been useful as there was some confusion at the start of the research about how important quantity was and how this could be related to counting skills. Later it was realised that what was missing was an understanding of subitising and numerosity and how these impacted on cardinality and ordinality. A test of the fundamental skills of subitising and numerocity would have made a better starting point as without these counting and ordering cannot take place. The test using a Fagan box (Paterson, 2001) appears complex and difficult to oversee, requiring two administrators. Developing a computer-based method of displaying the images would have been a feasible alternative for this group of participants and possibly a method of indicating their choice could be developed that does not rely on observing their pupils. Devising a computer-based test is more in keeping with design-based research method and would allow a laboratory approach to be used in the classroom. This same test could be developed to test numerosity and the comparison of group sizes.

From this research it was noted that there is a need to start by comparing just two sets and to progress to a greater number of sets, as the participants found the original task of ordering many sets too confusing. Some participants will progress more quickly to this stage than others.

The need to agree on terms with the participant also became apparent as the research progressed; spending time working out what terms such as more than, less than, greater or smaller would have been useful. This would allow the observer/researcher greater confidence that the responses received from the participant are due to their numerical ability and not an effect of miscomprehension. Insufficient time was spent preparing the participants and led to some confusion with the language used.

Ordinality

The greatest success with ordering and numerocity came with sets made up of food items. The need to create a desire for the participant to be involved and succeed is important and can have positive outcomes on the test. Not everyone is motivated by chocolate and fruit; therefore, spending time discovering what will motivate the participants would have been time well spent. This is also relevant to any pictorial representation used in a computer test developed for testing subitising and numerocity. The symbols will need to be stimulating to ensure engagement yet not distracting. Time experimenting with each individual to explore their preferences would help avoid any potential problems.

There is a need for tests that clearly measure the components of counting and the steps of developing the five elements of counting and that measure the ability to subitise and the ability to demonstrate numerocity, as well as a test to measure the ability to order sets of objects. Computerised tests would aid the researcher working on his or her own but there remains a need for tactile tests and for the transient nature of sound to explore greater skill and skill transference.

With these tests methods to improve and master the next developmental step or skill can be designed to meet the individual needs. This will ensure lifelong learning and progression or at least ensure the maintenance of skills already achieved. Tests that do not require a verbal response are necessary to assess the skills of participants such as David. If these cannot be designed then it would be advisable to make observations of the participant in his or her everyday life. This will hopefully generate some useful data that can be applied to develop intervention strategies that suit the personal needs of the participant.

The further education sector

There is a need to investigate the level of understanding of the elements of counting and the other basic numeracy skills within the staff working across the further education sector. If, as suspected, there is an overall deficiency in awareness there will remain the challenge of educating and training current staff and the need to review the teacher training curriculum. One of the initial objectives of this research was to assess whether time could be better spent in further education numeracy sessions. The initial premise was that much

time was wasted teaching skills that could not be learnt; what this research has shown is that the learners are still in early developmental stages and need to be taught at their own ability level. The crude measures used to determine these skills and what is assumed to be a lack of knowledge by the staff is the real problem. It is recommended that whether this combination is what leads to the frustration with teaching numbers in further education is further investigated.

The action research cycle

The initial prejudices felt towards qualitative research were, over the period of this research project, overcome. That this small-scale action research project, with so few participants, could generate so much data and lead into interesting areas was a revelation. The results may indicate that more research needs to be taken into developing a test of numeracy skills but the fact that there is now a clear understanding that the test needs to be more sensitive to the small increments in counting is of benefit. If this understanding was shared across the further education sector it is felt that better numeracy developmental sessions would take place. It is believed that there would be less frustration for the learners, the teachers, the trainers and the parents and carers. Expectation could be brought into line with a realistic assessment of numeracy ability, the knowledge of the next stages of development and the probable rates of improvement.

It was not felt initially that the results generated by four participants, who included one who could not speak and one who effectively dropped out, would be of greater value than opinion. Even if the results had been of little value

beyond those participating they were of value to them and that is the value of small-scale localised research. The extended society of the participants valued the results and to varying degrees have implemented the findings and advice. It must be noted that while observing a numeracy lesson four years after the research project, Gary T was seen to be struggling to count to ten. His new teacher, who has no formal numeracy training, appeared to have little knowledge of the best method to develop his skills and was attempting to make him add up by counting on. This was extremely disappointing, both for Gary individually and as it demonstrated the limitations of the method used to disseminate the information.

The dilemma for any researcher is that the information gathered is not used. Although as frustrating for the action researcher as for any other researcher there is a subtle difference in action research in that the participants own the results. The participants have the right to use or not use the results as they see fit. If the participants choose not to act on the results then that is their right, yet the lack of advocacy skills in these participants places a greater moral responsibility on the broader participants. These include the researcher, the teachers and the parents and carers, who need to ensure that the results are used to the best advantage of those who will benefit.

This action research project did not just affect the participants and the understanding of their numeracy skills; it also had a profound effect on the researcher. In abandoning the initial research question and adopting action research many preconceived ideas were challenged and prejudices exposed. The validity of action research and qualitative research has been accepted;

constructivism as a valid form of knowledge is established in the researcher's mind and also that small-scale participatory research is worthwhile and can have an impact. When answering Malvicini's (2000) question, 'Who really benefits from research questions in … education?', in the case of this research project, it is difficult not to concur fully with his answer 'does not the person asking the question benefit the most …?'

Appendix

Copy of the consent form given to parents

Thank you for allowing ……. to participate in this maths research project for my thesis.

…….. participation is entirely voluntary;

…….. can withdraw at any time.

The findings will be kept strictly confidential and will only be available to myself. Excerpts from sessions may appear in my final thesis, but under no circumstances will ……. name or any identifying characteristics be included in the thesis.

Please sign that you have read and agreed to the contents.

…….. (signed)

…….... (print)

Relationship to …….. is ……..

Please send me a copy of your findings on …… yes/no

I agree to the results being shared with the teaching staff at the college who teach …….. yes/no

Chapter 8

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